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REVIEW AND EVALUATION OF BUREAU OF LAND MANAGEMENT RANGELAND REMOTE SENSING

Final Report

January 18, 1985

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Denver Service Center, Bureau of Land Management

Performed Under Cooperative Agreement No. YA-551-CA4-340003
Task Order No. 1

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INTRODUCTION

On June 14 and 15, 1983, an internal Bureau of Land Management task force was convened at the Denver Service Center to make a review and set forth recommendations on the Bureau's remote sensing activities. Specific objectives of that task force were:

1. "Review the state-of-the-art with regard to remote sensing. This included a review of ongoing field efforts involving the use and testing of remote sensing on rangeland resources inventory and monitoring."

2. "Evaluate the capability of remote sensing to provide data in support of rangeland resource inventory and monitoring."

3. "Recommend additional work needed to further evaluate the capabilities of remote sensing."

4. "Recommend those techniques that are presently appropriate for documentation in a reference document."

Among other items, the task force suggested that "past and current research and development projects be evaluated to determine and document their potential in increasing the Bureau's knowledge and expertise and to determine their usefulness for Bureau of Land Management managers." It was suggested that a questionnaire be used to initiate the activity.

In February, 1984, and as a result of the above task force activities, the Director of the Denver Service Center was advised to:

1. "Prepare state-of-the-art guidelines on remote sensing systems including Landsat, other satellite data, and aerial photography in support of the Bureau of Land Management's (BLM's) planning and renewable resource management programs. These guidelines should include a literature review with an annotated bibliography. They should be designed so that the user can easily assess the current application of remote sensing."

2. "Conduct an evaluation of past and ongoing development projects involving remote sensing to determine their results and applicability to BLM's planning and renewable resource programs."

As a result of this advice, the Bureau of Land Management, Denver Service Center, and Colorado State University entered into a Cooperative Agreement (Agreement No. YA-551-CA4-340003) on July 13, 1984, wherein one of the mutually agreed upon objectives was: "To develop and apply faster and more efficient methods of managing rangeland and related resources, using remote sensing and computer technologies". Task Order No. 1 of the Agreement was executed August 14, 1984 (Appendix I). Specific tasks to be performed under the Task Order were:

Task 1. Review and evaluation of BLM renewable resource remote sensing activities and requirements.

This task consisted of two phases:

1. Develop mutually agreeable procedures for data collection to serve as the basis for the formal review and evaluation of BLM remote sensing operations and review and evaluate the remote sensing operations at the Denver Service Center.

2. A field review and evaluation of BLM rangeland and renewable resources remote sensing activities.

Task 2. Prepare a report of findings on BLM remote sensing activities and include recommendations on possible ways to implement state-of- the-art remote sensing technology for renewable resource activities.

The scope of the work was primarily related to range management remote sensing because this seemed to be the major interest and emphasis of the Bureau of Land Management with regard to remote sensing. Also, the time limit, 120 calendar days, subsequently amended to 180 days, and budget did not allow full evaluation of remote sensing for other specific resource systems such as wildlife/wildlife habitat, forestry, watershed, or aquatic systems. It should be realized, however, that many of the findings for

range management would be applicable to other resource systems.

The findings and recommendations which follow should be applicable for Bureau of Land Management rangeland resource inventory, monitoring, and assessment throughout the western United States, including Alaska.

DEFINITIONS

For clarity and understanding, it is important to define selected key-words and phrases.

1. RANGELAND - Land on which the native vegetation (climax or natural potential) is predominantly grasses, grass-like plants, forbs, and shrubs suitable for grazing or browsing use. Includes lands revegetated naturally or artificially to provide a forage cover that is managed like native vegetation. Rangelands include natural grasslands, savannahs, shrublands, most deserts, tundra, alpine communities, coastal marshes and wet meadows. (Range Term Glossary Committee 1974)

2. RANGE - Embraces rangelands and also many forest lands which support an understory or periodic cover of herbaceous or shrubby vegetation amenable to certain range management principles or practices (Range Term Glossary Committee 1974).

3. REMOTE SENSING - The science and art of obtaining information about an object, area, or phenomenon through the analysis of data acquired by a device that is not in contact with the object, area, or phenomenon (Lillesand and Kiefer 1976). Devices used to collect the data may be hand held cameras on the ground; cameras carried in helicopters, air-planes and satellites; multispectral scanners carried in airplanes or

satellites; radar systems; or microwave radiometers.

For the purposes of information reported herein, remote sensing relates only to cameras and aerial photographs produced by them and multispectral scanners which produce digital imagery such as acquired by the Landsat satellites. These two systems have been used most frequently by the Bureau of Land Management and other organizations for renewable natural resources. Other remote sensing systems are either inappropriate for renewable natural resources or the use and potential of them is still experimental.

4. NORMAL COLOR FILM - Film sensitive to blue, green, and red reflected energy which, when properly exposed and processed, results in a color image (picture) of a scene as observed by the unaided eye.

5. COLOR INFRARED FILM - Film sensitive to blue, green, red, and near infrared reflected energy which, when properly exposed and processed, results in a "false color" image of the scene. For example, "false color" means that dense, rapidly growing herbaceous vegetation will appear as reddish colors because of high reflectance of that kind of vegetation to near (photographic) infrared energy. The film is sensitive to imaging heat sources only if the emitted heat energy is high, e.g. lava flows.

6. BLACK AND WHITE PANCHROMATIC FILM - Film sensitive to blue, green, and red, reflected energy which, when properly exposed and processed, results in an image (picture) of the scene displayed as grey tones.

7. BLACK AND WHITE INFRARED FILM - Film sensitive to blue, green, red, and near infrared reflected energy, which, when properly exposed and

processed, results in an image (picture) of the scene displayed as grey tones. Items highly reflective of near infrared appear light in tone, i.e. rapidly growing herbaceous meadows. Items highly absorptive of near infrared energy appear dark in tone.

8. MULTISPECTRAL SCANNERS - Remote sensors which simultaneously collect data about a scene using an array of energy detectors calibrated for selected portions of the electromagnetic spectrum. Each detector obtains data in selected visible reflected energy wavelengths or emitted heat energy for thermal sensing. The basic data are in the form of electronic digital signals recorded on multichannel computer compatible tapes. The data can be either processed directly by the computer or reconstituted into a photo-like image of the scene for visual interpretation. Current Landsat data are collected by a multispectral scanner.

Table 1 presents a summary of remote sensing systems capabilities.

9. INVENTORY - The systematic collection and summarization of data and information about resources to determine what they are, where they are, and how much is available. Subsequent analysis of the data and information is performed to respond to alternative management scenarios. Sometimes data and information analysis are considered a part of inventory.

10. MONITORING - The systematic collection, analysis, and interpretation of resource data from selected areas to assess effects of management practices and evaluate progress toward management goals. Included in the monitoring process is the selection of specific areas for study and the identification of specific data and information items needed to indicate the effects of current management practices

Table 1: Kinds of Remote Sensing Systems by Wavelength Bands and Applications*

Sensor System	Wavelength Band Sensed	Kinds of information recorded and general uses
Scintillation counters	0.003 - 10 nanometers	Measures emitted natural radiation by gamma ray detectors. Useful for some mineral exploration (i.e. uranium), monitoring background radiation of mine spoils and other radioactive wastes. Experimentally used to measure snow depth and/or water content. Not used for renewable natural resources.
Scanners with photomultipliers; special cameras	10-400 nanometers (0.01 - 0.4 micrometers (um)	Records incident natural radiation with scanners. Records near to middle ultraviolet (.28 micrometers to .38 micrometers) reflectance with photographic film and quartz-lens cameras. Not used for renewable natural resources.
Cameras w/conventional B&W and color film	.4um - 7um	Normal photographic rendition of a scene within the visible portion of the spectrum utilizing reflected energy. Routinely used for natural resources by presenting a picture of the scene as normally seen.
Cameras w/B&W and color infrared film	.5um- 0.9um	"False" color photographs that, when properly exposed and processed, produce a photographic image of objects not the true version of the scene. Uses high reflectance properties of vegetation in photographic infrared (0.07um - 0.9um) to frequently improve vegetation analysis via aerial photographs.
Multispectral units	0.3um -0.9um	Multicamera systems in which each camera lens is filtered to pass specified wavelength bands. Information recorded usually on black and white panchromatic film. Used mostly experimentally for renewable natural resources.
Thermal Radiometers/ Scanners (infrared)	2.5um-14um (Thermal IR)	Generally measures total radiation (emitted heat) in selected wide bands in the infrared region (normally 3.5-5.5um and 8-14um). Imagery is obtained by scanners with infrared detectors. Initial data are in the form of electronic signals recorded on magnetic tape but are usually presented as a photograph displayed on a cathode-ray tube. Most notable uses of thermal infrared imagery for renewable natural resources are for fire detection and mapping, detection of some effluents in water bodies, and soil mapping. Some experimental uses have been for animal detection and counting.

Table 1: Kinds of Remote Sensing Systems by Wavelength Bands and Applications*

Sensor System	Wavelength Band Sensed	Kinds of information recorded and general uses
Spectrometers as scanners with photomultiplier detectors and/or infrared thermal detectors.	In any spectral region but currently for renewable natural resources between 0.3um and 14um	Multispectral scanners or multilinear arrays calibrated to collect spatially coherent reflected and/or emitted energy from a scene in selected wavelength bands (channels). Most notable current examples are the Landsat MSS and Thematic Mapper systems. Principal data form is digital on computer compatible tapes for immediate analysis. Basic data can be reconstituted to present a photo-like image of the scene. Depending on resolution, used for mapping vegetation and some other renewable natural resources with varying degrees of success.
Radars	1mm-1m	Mostly narrow band systems which present either analog data or photo-like imagery on film exposed from a cathode-ray tube. Not used for renewable natural resources in the United States, information is obtained more efficiently and effectively via photographic and scanner systems. Radar has been used successfully to map general vegetation in tropical rain/cloud forests because it generally is an "all-weather" remote sensing system.

* Not all sensors, such as laser and microwave radiometric systems, are included because they are currently either highly experimental or have no application to natural resources.

PROCEDURE

Field Visitations

Field visitations were made to three Bureau of Land Management State Offices (Idaho, Arizona, and New Mexico), selected associated District and Area Offices within each State, and the Riverside, California District Office. In addition, two visits were made to the Denver Service Center. The locations of field visits were selected by the Denver Service Center with the assumption the locations were representative of

past and current activities on remote sensing for range management and other renewable resource programs. Primary emphasis was placed on range and rangeland monitoring, recognizing overlapping relationships with other resource systems.

At each location, personal interviews were conducted with key personnel to:

1. Obtain data on information needs and requirements for range and rangeland monitoring and, if appropriate, inventory. It was recognized that some of the information needs and requirements would be applicable to other resource systems, especially wildlife habitat.

2. Review what kind of remote sensing activities had been conducted and the relative value to management decisions of the data and information gained through remote sensing.

3. Obtain information on current remote sensing activities and plans for future work.

Itineraries for the field visits and lists of people contacted are presented in Appendix II.

Questionnaires

In addition to the scheduled field visits, four questionnaires were submitted to all field offices to obtain data and information from all locations. Copies of the questionnaires are presented in Appendix III. One questionnaire was developed specifically to obtain perspectives on range remote sensing capabilities by Bureau of Land Management managers. Two additional questionnaires were designed for the resource specialists and other field personnel actively participating in resource monitoring/inventory activities. The last questionnaire was developed to obtain information from others on resource remote sensing and sugges-

tions for additional remote sensing development activities.

State Office Remote Sensing Coordinators were asked to provide wide distribution of the questionnaires and that key individuals with experience in specific resource areas had access to them. It was requested that all questionnaires be returned to the point of origin for review and summarization.

INFORMATION NEEDS

The preparation and initiation of any renewable natural resource inventory and monitoring plan must be preceded by determining what kinds of information are needed to answer specific questions. Questions, for example, about range management can be framed generally about determination of livestock carrying capacity or evaluating the effects of a specific grazing management program on vegetation and livestock performance. Once such questions have been defined, the kinds of data and information to collect can be determined and procedures for data collection can be defined, including data elements and information items potentially collectible by remote sensing.

It is doubtful that there will ever be complete agreement on what all data elements and information items are required for renewable resource inventory including requirements for rangelands. This should be expected. Many information needs are hierarchical in the sense that needs for some kinds of information prevail throughout a decision-making hierarchy. For example, information on range condition is required at the local level to assist in evaluating current range management practices; it is also needed at higher administrative levels to assist in

program planning for range improvement practices. Other kinds of information, such as regional demands for red meat production from rangelands, is of lesser importance at the local level but of major importance at higher administrative levels for assessing the state of regional or national rangeland situations. Also, changing political issues, resource management objectives, or required, expected, and unexpected tradeoffs within and among resource management objectives will affect information requirements. However, some basic data elements will likely be consistently required and can be grouped into five general categories

1) Area, extent, geographic location, and structure of plant communities.

2) Ecological successional stages of vegetation.

3) Substrate of the vegetation including soil and topography.

4) Water elements including kinds, amounts, extent, and duration of water bodies.

5) Faunal populations.

Area and extent of plant communities are normally accomplished by mapping. The plant communities mapped may be (1) inferred or real potential natural communities, (2) existing seral (successional) communities in relation to potential natural communities, or (3) both potential natural and seral communities. Almost universally, mapping conventions including selection of map scale and mapping unit size, will result in some mapped units representing complexes; the mapped unit delineation will include more than one primary mapping element. Mapping is normally accomplished by use of aerial photographs and, to some degree of success, Landsat digital image processing depending on level of classification to be mapped.

Structure of plant communities is of prime importance for renewable natural resources inventory and monitoring. Structure refers to the three dimensional picture of vegetation - length, width, and depth. For example, in a forest, vegetation tends to layer itself into trees, shrubs, grasses and in some cases mosses and other very low growing vegetation. Grasslands and shrublands usually exhibit similar layering attributes with some exceptions. For example, seeded monocultures such as crested wheatgrass usually represent a single layered community.. The structure of vegetation at any moment in time provides a measure of diversity within and among plant communities and, when evaluated in a time sequence, establishes changes in structure to assist in evaluating effects of management in relation to management goals. These changes lead to estimates of the seral stages of plant communities to evaluate the condition status of rangelands, for example, for specified kinds of animal grazing.

Plant community structure can be determined by obtaining data and information on one or more plant community attributes including:

1. Density - number of individuals per unit area.

2. Cover - either basal area or foliage cover (area).

3. Weight - either existing standing crop, phytomass (production of all above and below ground plant parts), new growth of the year, or net annual above ground primary production.

4. Frequency - percent occurrence of a species in a set of plots, a measure of presence or absence.

5. Height - height of the individuals of the stand such as an individual

tree, shrub, or grass plants, or the height of the stand of trees, shrubs, or grasses.

6. Age - the age of the individual or the age distribution of all individuals within a stand, usually by species.

7. Form class - a relative description of the appearance of a plant, usually shrubs, as a result of grazing or browsing pressure or, the form of a tree trunk in relation to a geometric solid.

8. Reproduction - new (young) and established individuals in the plant community, usually two years old or older.

Table 2 summarizes, in general, demonstrated capabilities of different kinds of aerial photography, the Landsat system, and the National Oceanic and Atmospheric Administration meteorological satellite system to provide data and information on the above attributes and includes water bodies. Information about the capabilities of radar, laser, and the SPOT satellite system is not included in the table because their demonstrated capabilities are not known.

Radar has an all weather capability which permits imagery to be acquired during night or day, through clouds and most precipitation conditions, and haze. It has been used to facilitate physiographic differentiation, general geological reconnaissance mapping, and some broad vegetation classifications. However, there has been no demonstrated operational capability of radar for renewable natural resources except generalized vegetation mapping in the tropics. Laser system applications for renewable natural resources are in formative stages. The SPOT satellite system has not been launched.

TABLE 2: Information Requirements in Relation to Remote Sensor Systems[1]

Codes for Information Item Recognition and Definition[2]
First code = Probability
Second code in ( ) = Smallest Scale Usable

Information Item	Remote Sensing Product						
	Cameras/Aerial Photographs[3]				Landsat[4]		NOAA[5]
	BW	IR	CIR	Normal Color	MSS	TM	AVHRR
Plant Community Level of Classification[6]							
1	H(VS)	H(VS)	H(VS)	H(VS)	H	H	H
2	H(S)	H(S)	H(S)	H(S)	H-L	H-L	LO
3	L(M)	I	H(M)	H(M)	I-N	I	N
4	I	I	L(M)	L(M)	N	N	N
Individual Plant Species Identification[7]							
Trees	Lo(L)	Lo(L)	H(L)	H(L)	N	I	N
Shrubs	Lo(L)	Lo(L)	H(L)	L(L)	N	N	N
Grasses	N	N	Lo(L)	Lo(L)	N	N	N
Individual Plant Species Height							
Trees	H(M)	Lo(M)	H(M)	H(M)	N	N	N
Shrubs	N	N	L(L)	L(L)	N	N	N
Grasses	N	N	N	N	N	N	N
Individual Plant Species Weight							
Trees	N	N	N	N	N	N	N
Shrubs	N	N	N	N	N	N	N
Grasses	N	N	N	N	N	N	N
Individual Plant Species Age							
Trees	Not possible except as inferred by stand size classes.						
Shrubs	N	N	N	N	N	N	N
Grasses	N	N	N	N	N	N	N
Individual Plant Species Form Class	Not possible for any species						

[1], [2], [3], [4], [5], [6], [7], appear at end of table.

TABLE 2 (Continued)

Information Item	Cameras/Aerial Photographs: BW	Cameras/Aerial Photographs: IR	Cameras/Aerial Photographs: CIR	Cameras/Aerial Photographs: Normal Color	Landsat: MSS	Landsat: TM	NOAA: AVHRR
Individual Plant Species							
Reproduction							
Trees	L(L)	I(L)	L(L)	L(L)			
Shrubs	N	N	N	N	N	N	N
Grasses		N	N	N	N	N	N
Plant Community							
Foliage Cover (View from top)							
Forestland	H(M)	H(M)	H(M)	H(M)	L:>25% cover	L:>25% cover	N
Shrubland	H(L)	I(L)	H(L)	H(L)	Lo	Lo	N
Grassland	L(L)	I(L)	H(L)	H(L)	N	N	N
Water (Assumes water body is visable from above)							
Rivers	H(VS)	H(VS)	H(VS)	H(VS)	H	H	H
Streams	H(S)	H(S)	H(S)	H(VS)	L	L	L
Ponds	H(M)	H(M)	H(M)	H(M)	Lo	L	Lo
Lakes	H(VS)	H(VS)	H(VS)	H(VS)	H	H	H

[1]Information in the table is generalized due to many interactive features of the scene imaged such as amount of vegetation cover; color, size, shape and other characteristics of features in the imaged scene; contrast, among items in the scene; time of year imagery is secured; and others. Also, the finest detail recorded on photographic film can be observed only by magnification. See also Aldrich (1979)

[2]Codes for Information Item Recognition and Definition.
Scale: L = Large Scale (1:100-1:2000); M = Medium or Normal Scale (1:12,000-1:30,000); S = Small Scale (1:30,000-1:80,000); VS = Very Small Scale 1:100,000 or less).
Scale (S = f/H) is a function of aircraft/spacecraft flying height above ground (H') and camera lens focal length (f). Scale for Landsat MSS and TM data and NOAA AVHRR data is irrelevant since the capabilities of those systems to detect and/or identify land surface objects is a function of the instantaneous field of view (the smallest ground area at an instant in time) of the scanners; for Landsat MSS, approximately 1.1 acres; for Landsat TM, approximately 0.2 acres; for AVHRR, approximately 300 acres at nadir.
Probability of Identification: Assumes use of primary data from the appropriate remote sensor without using other data sources, with normal scene contrast, and with normal mixtures of surface features, i.e. two or more kinds of coniferous forest species in the same scene. H = High, L = Likely, Lo = Low, I = Improbable, N = Not Possible.

[3]BW-black and white panchromatic; IR-black and white infrared; CIR-color infrared, color-normal color.

[4]MSS - four band multispectral scanner; TM - Thematic Mapper (a seven band multispectral scanner; TM data has not been fully evaluated.)

[5]National Oceanic and Atmospheric Administration meteorological satellite with an Advanced Very High Resolution Radiometer. A four channel scanning radiometer system being evaluated by Bureau of Land Management for fire fuels mapping.

[6]Plant Community Level Classification: Generalized for illustrative purposes only but is similar in context to that used by Bureau of Land Management in Landsat demonstration tests and by Driscoll, et al (1984)

1 - Very general (Formation) such as grassland
2 - More specific (Subformation) such as shortgrass grassland
3 - More specific (Series) such as blue grama/buffalo grass
4 - Most specific (Association) such as blue grama/buffalo grass/prickly pear grassland.

[7]It follows that if the species cannot be identified, information on cover, weight (production), frequency, height, age, form class, reproduction or other characteristics about the species cannot be discerned. If the species can be identified, density, cover, and frequency can generally be determined using similar remote sensing data as for species identification.

Information on substrate of vegetation, primarily soil and topography, is needed to understand plant community-plant-soil relationships, potential erosiveness of the landscape, and operability of the landscape for such activities as logging, engineering and grazing opportunities. The information on soil and topography is usually obtained with the assistance of aerial photographs and in some cases, Landsat data. Soil surveys are usually initiated by mapping vegetation with aerial photographs, using vegetation as a surrogate in the first approximation of a kind of soil.

Water elements, including area and extent of man-made and natural impoundments and streams and rivers, are usually mapped most efficiently using aerial photographs and/or Landsat imagery. The sensor system to use depends on the size of the water body and the resolution of the sensor system.

Information on faunal populations, especially large wild herbivores, is needed to assist in making forage allocations among the animals to negate serious conflict. Animal censuses are made by ground observations, aerial visual observations, and sometimes aerial photographs. Most animal censuses are done by ground-based procedures and aerial visual observations from airplanes or helicopters. Depending on circumstances, such as time of year and gregariousness of the animals, aerial photographs have been used successfully to estimate animal populations, either by direct count or by activity inferences such as holes in the ground, earth mounds, or other evidences of animal presence that can be detected by aerial photographs. Thermal imagery has been used with limited success to detect certain large animals.

RANGELAND REMOTE SENSING: STATE-OF-THE-ART

Remote sensing to assist in rangeland management and planning is not new. Black and white panchromatic aerial photographs have been accepted assets to range inventory since 1937 (Interagency Range Survey Committee, 1937). During the 1940`s and early 1950`s, it became apparent to range managers and range technicians that aerial photographs could be used effectively and efficiently to (1) map range and other vegetation types more consistently and accurately, as compared to using ground based techniques only, (2) identify and stratify sampling strata and select and locate sample plots more rapidly, and (3) perform some selected field work associated with range inventories (Reid et al. 1942, Clouston 1950, Harris 1951). Aerial photography was found to be superior to the grid traverse, planimetric, topographic and formline mapping methods used in early range surveys despite the fact that the photography was not acquired with optimum specifications and quality.

In the decade of the 1960`s, many events converged to make range resources applications one of the most rapidly advancing fields in remote sensing. This was caused by development of new and improved aerial films and aerial cameras, development of different kinds of remote sensors such as multispectral scanners, and improved vehicles for carrying remote sensors such as high flying airplanes and space satellites. The following briefly describes some remote sensing techniques developed over the past approximately 15 years for range resource inventory and monitoring with specific reference to plant communities and individual plant species. More detail has been presented by Poulton

et al. (1975) and Carneggie et al. (1983). In addition, a selected list of references is presented in Appendix IV.

Mapping

Some information needs about range can often be satisfied, at least in part, through cartographic presentation of the data. This requires mapping certain landscape features and plant communities. Mapping plant communities infers developing a classification for plant communities, a range information need. Therefore, the relationship between mapping plant communities at some classification level and remotely sensed data must be understood.

Generally, two factors determine the degree of interpreted or image processed detail from aerial photographs or multispectral scanner data: (1) the scale of the photographs or the ground resolution of the scanner data, and (2) the ultimate use of the data and information derived from the remote sensors. Consequently, the classification/mapping accuracy attainable at each level of classification, presuming a hierarchical classification system, is determined by the scale and/or ground resolution of the remote sensor. For example, aerial photo mapping for range plant communities is often constrained to a 40-acre minimum, except for some highly productive classes such as herbaceous meadows when the minimum mapping area suggested is 5 acres. Plant communities at any level of classification do not arrange themselves into discrete units and patterns of uniform size. Therefore, synonymity of mapping units and plant community classification units should not be expected except for large expanses of a kind of plant community perpetuating itself within a specified effective environment, e.g., blue grama-buffalo grass

shortgrass communities in the shortgrass plains. Consequently, most mapping units may need to be defined in terms of two or more plant community classification units especially when dealing with the lower levels of a classification hierarchy. These mapping units are called complexes and, for information display, the proportion of each classification unit within the mapped complex should be determined.

Assume availability of resource aerial photography with a nominal scale of 1:15,840. This scale is equivalent to 4 inches per mile or 40 acres per square inch. Matching a single mapping unit to be equivalent to a classification unit less than 10 acres would frequently produce a complex array of data on a map and make it difficult to read and understand, especially when mapping in complex topography. In addition, small but biologically important classification units would be overlooked in the mapping process because of small area coverage and minimum unit map size constraint. The result would be a distorted picture of the resource classes. This relationship between remote sensing data and range resource classification and mapping has been discussed by Poulton et al. (1969).

Aerial Photographs and Range Monitoring/Inventory

Aerial cameras and film have improved significantly over the past 20 years. Most current contracts for resource photography specify the use of precision cameras with a resolving power at least four times greater (40 line pairs per millimeter) than the older cameras. Current resource managers and specialists who use aerial photographs may be unaware of improved camera resolution. Consequently, when presented with an option of using small scale (1:30,000-1:80,000) aerial

photography or normal scale (1:12,000-1:30,000) aerial photography, the normal scale photography will be selected because of familiarity with its use and lack of knowledge that the small scale photography will likely have equivalent or increased information content.

Current aerial film emulsions are coated onto non-shrink polyester film material that improves durability and maintains image information longer as compared to earlier uncoated paper products. Newer films are finer grained and have increased sensitivities compared to pre-1960 films. The newer films can also be obtained in a variety of emulsions: black and white panchromatic and infrared, color negative, color positive, and color infrared. For these reasons, and the fact that photointerpreters using color aerial photography deal with three color dimensions (hue, value and chroma) rather than shades of grey as with black and white photography, emphasis has increased on use of color aerial photography for most range resource monitoring/inventory purposes.

Applications of aerial photography for range monitoring / inventory have been designed to improve the recognition and mapping of plant communities, quantify characteristics of those plant communities, and detect and measure changes in the communities arising from natural or man-caused events.

Plant communities can be interpreted and mapped about equally well on normal color and color infrared aerial photographs at scales (1:12,000-1:30,000) normally used for that purpose (Driscoll 1974). However, as photointerpreters become familiar with color infrared aerial photographs, especially with scales smaller than 1:30,000, color infrared photographs provide more discriminate differences among plant

community systems (Driscoll 1971, Aldrich 1981, Batson and Elliott 1977). This is because color infrared photographs are taken with an atmospheric haze penetration filter, color infrared film is sensitive to near infrared reflectance, and vegetation is an excellent near infrared reflector. Thus, clearer pictures are possible from high altitude than are obtained with normal color or black and white film. However, in many arid and semi-arid rangeland regions, the natural scarcity of vegetation cover makes vegetation mapping from any kind of photographs difficult. Frequently, the image signature on the photograph is not primarily due to vegetation. Rather, it is an integrated vegetation-soil signature that is strongly influenced by vertically exposed geologic parent material and associated soils. In general, although factual published data were not found, in areas where vegetation cover is less than 25-35 percent, the resultant photo-image is profoundly influenced by soil surface features, especially color.

Since the late 1960's, considerable information has become available on use of large scale (1:100-1:2,000; usually 1:600-1:1,200) aerial photographs for range monitoring (Carneggie and Reppert 1968; Lorain 1970; Carneggie et al. 1971; Tueller et al. 1972; Carneggie 1972; Driscoll and Coleman 1974; Colwell et al. 1975; Driscoll et al. 1970; Thomas and DeGloria 1979; Driscoll et al. 1972; Driscoll et al. 1974; Meyer 1976). Aerial photographs were used to: (1) detect and identify plant species, (2) measure plant height, foliar cover and plant density, (3) measure changes in some plant parameters at intervals, (4) estimate herbaceous standing crop, and (5) detect and quantify some soil surface characteristics such as amount of bare soil and plant litter.

The extent to which precise interpretations and measurements can be made with sufficient accuracy for monitoring changes in plant communities with large scale photography depends on: (1) the adequacy of high quality, large-scale photographs taken at two or more dates over the same ground area; (2) the techniques used for making interpretations and measurements on the photographs; (3) the kind and amount of supporting observations and measurements made on the ground; and (4) the characteristics of the plant community being monitored.

The following items should be considered when attempting to secure high quality large-scale aerial photographs over permanently located areas for range monitoring purposes:

1. Establish permanent plots or transects.
2. Acquire sequential photographs at approximately the same scale, resolution, exposure, time of day, and plant development stage.
3. Select a camera and lens system that meet project objectives.
4. Specify type of aircraft and flying altitude to meet project objectives.
5. Select film type and acquisition date.
6. Select appropriate vegetation units to evaluate.
7. Specify ground measurements and observations to be made in the field on the date of photography.
8. Specify photo interpretation and photo measurement techniques.
9. Repetitive photographic coverage should be obtained at two to five year intervals.
10. Photographic records should be filed so that they will not be damaged, will not deteriorate, and are a part of the permanent

record, together with ground data, of the specific study location.

Carneggie et al. (1983) discussed these items in more detail, but in general: (1) color infrared film is the preferred film type for identifying individual plant species; (2) film scales smaller than 1:1,200 are inappropriate for shrub identification and measurement; (3) film scales larger that 1:500 are required for those herbaceous species which can be identified according to research results; (4) all individuals of species which can be identified may not be detected because of small size (immaturity), they are ingrown with other members of the same species, or are hidden beneath the crowns or in the shadows of other plants; (5) most plants can be more easily identified from photographs taken during the middle to latter part of the growing season; and (6) the more complex (species diversity) the plant community, the more difficult it will be to obtain acceptable identifications and measurements of individual plants.

Standard format (9 x 9-in.) cameras are usually inappropriate to secure aerial photos for range plant species identification and measurement. Lens shutter speeds and film cycling mechanisms are too slow to stop image motion and secure stereoscopic coverage of selected areas for species identification and measurement. Usually rapid cycling, 70 mm or 35 mm cameras mounted in fixed wing aircraft, or dual mounted cameras, (for stereoscopic coverage) of the same format mounted in helicopters, are required to secure the kinds of aerial photographs needed. Meyer and Grumstrup (1978) and Meyer et al. (1982) describe operational procedures for using 35 mm cameras for range investigations.

It is not feasible to cover large tracts of land with large scale, small format aerial photography because of expense and large volumes of photographs. Therefore, sampling schemes may need to be established if statistical information is needed about certain parameters. Also, specific plots or areas to be photographed with large scale photographs need to be documented. If statistical sampling is desired or needed, some schemes have been developed which are based on multistage probability techniques (Driscoll 1969; Langley 1971).

Ground Photographs and Range Monitoring/Inventory

Most ground based range monitoring techniques have, as part of the system, a requirement to obtain oblique photographs of the general area of study. The photographs provide a visual record of the location and an opportunity to qualitatively evaluate changes via photo comparisons between two time periods. Since cameras have been readily available, ecologists have photographed established ground plots to obtain a permanent, visual record of vegetation (Hastings and Turner 1965). However, these photographs have been used in a qualitative sense, e.g., there is a difference, with no attempt to obtain quantitative data.

Within the past two decades, vertical ground photographs have been used to identify plants and estimate plant foliar cover (Claveran 1966, Wimbush et al. 1967, Pierce and Eddleman 1970, and Wells 1971). The photographs are taken either with one or two small format (i.e., 35 mm) cameras mounted on a tripod or four-legged stand vertically above a designated plot area. The resulting pictures can be interpreted either stereoscopically, if two cameras are correctly mounted to provide picture overlays, or monoscopically, with only one picture.

Wells (1971), devised an interpretation system for estimating plant foliar cover from vertical ground photographs. The photo transparency is placed on a viewing platform and moved at specified increments beneath cross-hairs imbedded in a magnifying viewing lens. Each time the photograph was moved, a record was made of the plant, soil, or litter material intersected by the cross-hairs. The technique is a modification of the dot-grid technique sometimes used on aerial photographs to secure area statistics. Other techniques for estimating foliar cover from ground and large scale aerial photographs include: (1) dot-grids (Poulton et al. 1969) and (2) line intercept (Driscoll 1970, Carneggie et al. 1971, Meyer and Grumstrup 1978).

Even with ultra large scale ground-based vertical photographs, not all plant species can be identified to ultimately obtain quantified data about them from the photographs. In some plant communities where numbers, foliar cover and diversity are great, the plant canopies overlap. In these situations, some species and individuals are overtopped or their canopies intermingle with other species or individuals making it impossible to account for all plants by viewing the photographs. Furthermore, some species, such as grasses in vegetative growth stages, are so similar morphologically that they cannot be identified using ground based photographs; it is often difficult to identify some grass species when examined directly. Also, when species of substantial stature (higher than the camera mount) occur in the community of interest, information about them cannot be obtained unless the camera platform is extended above the tallest plant canopy, such as in high shrub communities. However, ground based vertical photos of relatively open, low stature communities can be useful for constructing plant species maps on

small plots which, when compared to subsequent photographs, can provide some inferences on range trend. It should be noted that securing ground based vertical photographs requires transporting bulky equipment in the field, a difficult task when foot travel is the sole mode of transportation.

Landsat Imagery and Range Monitoring/Inventory

The astronauts of the Mercury and Gemini space programs in the 1960's brought back spectacular photos of Earth from space, although many believed such photos would not be possible because of atmospheric scattering of light energy. These successes, although not designed for earth resources, led to the satellite earth resources program. In March 1969, a part of the Apollo IX mission was dedicated to earth resources experiments using 70 mm cameras.

Color infrared photos from the Apollo IX mission were encouraging for the analysis of natural vegetation. For range resources, these photos from space provided sufficient color rendition and spatial resolution to allow generalized classification of plant communities in desert ecosystems (Poulton et al. 1969). However, the space photos had to be supplemented with high resolution, multi-scale aircraft photos to determine the areal extent of specific plant communities within generalized systems and the component makeup of those communities (Driscoll 1969).

Research from the Apollo IX photography and evaluations of the Mercury and Gemini photographs of Earth contributed to the development and flight of the Earth Resources Technology Satellite (ERTS) series, now known as the Landsat series, beginning in July 1972. The first Landsat

satellite had two independent imaging systems, three vidicon cameras and a 4-band multispectral scanner, designed to collect earth resources information in reflected visible and near infrared wavelengths. The vidicon cameras soon failed and Landsat image analysis has been based on either computer compatible digital data tapes or hard copy imagery prepared from the digital data. The digital data tapes include information recorded from reflected energy in the green, red and two near infrared wavelengths and are used independently or simultaneously for analysis. The hard copy photographs are either representations of each wavelength or combinations of them. The most usual is a color infrared photographic representation prepared by combining the green, red, and one of the reflected near infrared wavelengths. The most recent Landsat system, LANDSAT 5, includes a Thematic Mapper. This is a multispectral scanner system which, in addition to six reflected energy detectors, ranging from the blue to mid-infrared portion of the spectrum, includes a thermal infrared energy detector. Spatial resolution has also been significantly improved but data from the Thematic Mapper have been analyzed only cursorily and will not be discussed. Only results from analyses of the Landsat multispectral scanner data, with a nominal resolution of 1.1-acre, will be discussed. The 1.1-acre resolution, a pixel, represents the area of ground seen by the Landsat scanner at any instant in time and the data element represents the integrated effects of all objects in the 1.1-acre. A normal Landsat scene represents approximately 10,000 sq. mi., 6.4 million acres, or 5.8 million pixels.

Early results of analysis of Landsat data for land cover classification, both computer assisted analysis and manual interpretation of color infrared photo-like images, showed that a Level II classification

was the most acceptable that could be accomplished (Driscoll and Francis 1975). Level II represents land cover classifications such as Deciduous Treeland, Shortgrass Grassland and Evergreen Shrubland. In some situations with high scene contrast, such as monospecies Wet Meadows adjacent to Upland Grassland or monospecies Deciduous Treeland (e.g., aspen) adjacent to Coniferous Treeland, a Level III classification can be accomplished. Similarly, a Level III classification for any kind of land cover can be accomplished if only one kind of Level III class is represented in the scene. As reported by Driscoll and Francis (1975), an accuracy assessment of forest and rangeland plant communities to Level II was 70 percent; for Level III, 48 percent.

Since 1975, use of time-sequential Landsat images (Landsat images of the same areas but acquired on different dates) improved mapping and classification of Level I and Level II classes and in some cases more specific classes (Tueller et al. 1975, Hironaka et al. 1976). Also, areas where severe changes occur such as fire, elimination of woody species by chemical or mechanical means including timbering via clear-cutting, and successful creation of monospecific stands of seeded rangelands can be detected by Landsat data (Driscoll and Francis 1975, Tueller et al. 1975, Hironaka et al. 1976).

Several instances have been reported whereby ancillary resource data is merged with Landsat data to improve classification results. How this has been done was reviewed by Johnson and Rohde (1981). Generally, topographic, geographic, vegetation, climatic, soils, or other kinds of data are merged with the Landsat data which is then constrained to avoid classifying a land cover unit where it is known not to exist. These

procedures do not improve on the basic data from the Landsat multispectral scanner, they only sometimes avoid classifying units where they do not exist or present pseudo-map overlays of information on the basic Landsat map.

Several investigators have experimented with surface albedo measurements derived from Landsat data to quantify surface changes due to grazing (Otterman and Fraser 1976; Robinove 1981; Robinove et al. 1981). Robinove et al. (1981) calculated the albedo value for each Landsat pixel to create an albedo image. By registering albedo images from different Landsat scenes, areas of increased or decreased albedo were identified. It was determined that these areas related to changes in soil moisture, erosional deposition following flooding, and changes in foliar cover of vegetation. Robinove et al. (1981) have suggested the experimental use of the technique to monitor terrain changes in arid and semi-arid regions.

The level of map detail which can be interpreted from Landsat imagery, regardless of analysis procedures used, depends on several factors: (1) the subject to map (e.g. land systems, land forms, soil, vegetation), (2) the spatial complexity of the landscape, (3) the spectral contrasts among the subjects being mapped, and (4) the date of the imagery. A thorough knowledge of the area to be mapped (classified) and as much supporting information as can be obtained is required.

In summary, results of research and applications of using Landsat multispectral scanner imagery for mapping (classifying) land surface cover indicate that, at best, it is most appropriate for Level II (very general) classifications unless high scene contrasts between lower

levels of classification exist in the imagery. The imagery cannot provide information on specific plant community structure or lower levels of classification except by inference.

Information on kinds of range information for monitoring or inventory purposes obtainable from Landsat imagery has been summarized in Table 2.

FINDINGS

During the field visitations, managers and resource specialists responsible for resource monitoring and inventory were interviewed with the objectives to obtain information on data needs and requirements; resource remote sensing activities completed, underway, or planned at the location; and the value of remote sensing products produced through recent remote sensing projects. Also, questionnaires returned from the field were reviewed and evaluated and summaries prepared for activity highlights. Although the current task order was designed most specifically to the Bureau of Land Management rangeland program, the findings and recommendations are generally applicable to other resource programs.

Summary comments for the field visitations are presented below. State-by-state summaries of the responses from 160 questionnaires returned are presented in Appendix V. Copies of the original questionnaire responses are available from the Branch of Remote Sensing (D-442), Denver Service Center, upon request. Interpretation and evaluation of the information obtained from the field visits and questionnaires are incorporated into the subsequent List of Findings in this section of the report and the Recommendations section of the report.

Denver Service Center

Individuals contacted at the Denver Service Center included personnel from the Director's Office, the Division of Resource Systems, and the Division of Advanced Data Technology.

It was emphasized by the persons contacted that the Bureau of Land Management is a highly decentralized organization in that field offices are delegated the independent responsibility of preparing resource information needs and requirements for resource monitoring and inventory and developing field measurement techniques to collect the identified information needs. There appears to be no central theme on information needs and requirements within the Bureau except generalized items such as the requirement to prepare information on range condition and trend. Since there are many different ways to measure and interpret range condition and trend with different kinds of data elements, such as plant foliar cover, density, production, frequency and others, there is a danger of a proliferation of perceived information needs and data elements and measurement techniques that could likely be incompatible for data and information merger and aggregation.

Regarding range management, it was stated that the major effort is now on rangeland monitoring and that range resource inventory was stabilized; little additional effort is to be expended toward inventory. An exception would be on problem allotments where a complete inventory would be required to resolve issues. Concerning monitoring, emphasis is on the key area/key species concept with major monitoring activities on the "I" allotments (areas where the probability of improvement is high because of inherent high productivity potential).

Recent past (1980 to present) remote sensing activities at the Denver Service Center have been devoted to evaluation of Landsat multispectral scanner data for resource inventories and monitoring. Technicolor Government Services, Inc., has been the prime contractor to assist in this endeavor, although some work has been done with the USGS EROS Data Center. The Landsat data were used for developing land use-land cover maps upon which slope and elevation themes were superimposed. The analysis process adhered to normal Landsat multispectral digital analysis procedures. We were told that the Image Analysis Group worked closely with, and involved, field personnel through specific projects. This may be true now but, as discussed later, such interaction did not always occur, according to field personnel. Accuracy assessments of the products of the Landsat classifications were generally not conducted by the Denver Service Center Image Analysis Group. Accuracy assessments, if any, were conducted by the recipients of the products. According to resource specialists at the Denver Service Center, Landsat products are of little or no value to their specific resource programs developed at the Service Center.

Although specific project plans for Denver Service Center Landsat projects were not reviewed, it was inferred by the interviewers that the plans were quite general in terms of objectives, responsibilities, planned and expected products, and time requirements for product delivery. This often led to misunderstandings between the data processors and product users and sometimes caused friction among the participating units.

Recent work on use of aerial photography at the Denver Service

Center has been devoted to riparian area evaluation and monitoring using large to normal scale color infrared aerial photography. The photographs are interpreted for vegetation cover types and foliar cover of trees, shrubs, and herbaceous species. Results of this work are not presently documented.

Remote sensing training at and through the Denver Service Center is mostly on a demand basis. Field offices are aware of the opportunity and request assistance as they deem it is needed. Two general courses have been available: (1) basic photointerpretation and (2) digital image processing. It was learned that remote sensing knowledge of students who had participated in the courses was nil prior to taking the courses.

Idaho

Individuals contacted during the Idaho visit included the State Director and some of his staff, and personnel from the Boise, Shoshone, Burley, and Idaho Falls Districts. Also, two individuals from the Vale District, Oregon, were contacted regarding use of aerial photography for riparian evaluation. The Idaho State Director and his staff interviewed presented valuable insights because of involvement of work with states where the Application System Verification Tests were conducted during the late 1970's (Alaska, Arizona and Idaho). The State Director remains optimistic about the application of remote sensing techniques for resource inventory but feels the Bureau has not always applied the lessons learned from those activities. The Director also believes that all levels of the Bureau, especially upper management, need to become more

aware of remote sensing techniques.

The Deputy State Director for Lands and Renewable Resources, who occupied a similar position in Arizona, indicated that some field personnel in Arizona believed that much of the Landsat classification work was providing information that was already available from other sources. He mentioned that if this were true, efforts needed to be directed to acquiring data needed for resource monitoring and inventory. The Branch Chief of Range and Wildlife was recently involved in an Idaho state review of Remote Sensing/Geographic Information Systems activities. He felt that there was a great need for a Bureau policy for a remote sensing program. He suggested that this policy include the following:

1. Proper use of satellite imagery and especially analysis of the digital data.

2. Acquisition and use of different scales and formats of aerial photography.

3. Acquisition and use of large scale photography for monitoring.

4. Training requirements.

The Shoshone District has been utilizing low altitude 35mm photography to evaluate and monitor key riparian areas. They are enthusiastic about the utility of the photography but are concerned about how to acquire the photos. The Cascade Resource Area is currently involved in a Landsat vegetation classification project using the Idaho Image Analysis Facility in Boise. This facility evolved from NASA technology transfer operations in the late 1970s and is located in the Idaho

Department of Water Resources. The resource area personnel are very supportive of local processing capabilities. It gives them close proximity to work with the data processing on a day to day basis. Regarding digital image processing of Landsat data, the state feels that the Idaho Applications Systems Verification Test was never completed. Apparently, budget constraints forced curtailment.

The Cascade Landsat Project (Boise District) is a cooperative effort between the Idaho State Office, the Boise District Office, the Soil Conservation Service and the Idaho Department of Water Resources. The Denver Service Center is not involved in the project. They stated that by employing intensive stratification and rigorous field verification on a regular basis, vegetation could be classified to Level III and sometimes to Level IV. The Resource Area personnel are optimistic that local Landsat image processing will yield acceptable products. It was noted, however, that intensive stratification meant interlayering data into the Landsat maps that was beyond the capability of the basic Landsat data.

The Soda Springs Project (Idaho Falls District) was considered an ill-defined project that did not produce expected outputs. This was probably caused by lack of detailed project planning and communications between project location personnel and Denver Service Center.

Idaho personnel indicate that they continue to have insufficient funds to procure aerial photography for the field offices. Many photos are outdated or of poor quality. This problem was mentioned at all levels of the organization. There is a willingness to investigate the use of available National High Altitude Program color infrared photographs

to fill this need. The photographs could be used in normal format or enlarged. Use of enlargements would necessitate special handling and storage procedures.

Idaho has been active in evaluating use of low altitude aerial photographs, primarily through the efforts of the Remote Sensing Coordinator. Most of the evaluations relate to riparian monitoring using primarily 35mm format photographs that were acquired in-house. Personnel involved, including the managers, believe it has high potential to assist monitoring of those areas. However, acquisition of high quality photos on a regular basis remains a problem. Some upland sites and burned areas have also been photographed. It was stated that upland sites appear to be more difficult to monitor using low altitude photos than riparian sites because of lower vegetation cover. It was learned that the State had adopted a multi-agency plan for minimum monitoring standards. Plant frequency was selected as the primary data element for monitoring changes or trends in vegetation.

During most interviews, it was learned that Bureau personnel were not adequately trained or equipped to use the types of remote sensing material that could be available at the field level. Most colleges and universities offer remote sensing courses only as electives and there is apparently little encouragement to the students to take the courses. The Bureau has attempted to minimize the problem with Bureau-wide training opportunities but only a few personnel take advantage of the training either because they are unaware of the training opportunities or budget constraints prohibit participation.

While visiting Idaho, work with a remote sensing analysis technique which utilizes video images for photo, map, and map overlay manipulation and quantification was discussed. A two-year evaluation of the technique ended in October, 1984, with a final report by the Idaho State Office. This report can be obtained either through the Idaho State Office or the Branch of Remote Sensing at the Denver Service Center. The author of the report, W. Doug Harrison, was the remote sensing specialist for the Bureau in the State Office from 1981-1984. Mr. Harrison did an excellent job documenting all facets of the system and the Bureau is encouraged to disseminate the report widely.

The video image analysis system evaluated is known as the System II, manufactured by the Measuronics Corporation. The System II captures data with videocameras in an analog form and converts it into a digital format using an micro-computer. Data can be entered into the system from maps, photos or videotape. Remotely sensed data input can be in the form of aerial photographic prints or transparencies in various formats; 9 x 9-in., 70 mm, or 35 mm. Images and maps can be scaled and registered to each other. The System II was evaluated for two general reasons: (1) the potential semi-automation of aerial photo interpretation, and (2) compilation of some basic resource data. Specialized analytical software had been developed and used experimentally to:

1) Measure area and perimeter of polygons.

2) Calculate foliar cover of some species using density slicing techniques.

3) Measure land feature change.

4) Perform image-to-image overlay and registration.

The automation of aerial photo interpretation is attempted by grey-scale density slicing procedures to identify and quantify surface features. The procedure can succeed only if the ground feature is distinct enough to allow a particular grey-level to be assigned and not be confused with other features in the scene. There are many factors which create problems in automation of interpretation including sun angle, slope, aspect and diversity of vegetation. Density slicing techniques and hence, semi-automated interpretation would likely be unsuitable for much of the landscape in the West. The technique may be helpful in some instances where there are high photo image contrasts among features in a scene such as rangeland seedings, riparian sites, and some shrub sites.

A second major function of the System II as used in the Idaho evaluation would be for resource data compilation. The resource data polygons, which appear on overlays, are registered and scaled to a map base. These resource polygons are recorded by the System II video cameras. Areas can then be calculated and tabular summaries of, for example, surface ownership or allotments, can be produced. Two Idaho Districts demonstrated significant savings by using the System II for this purpose. The system is apparently quite user friendly and experience has indicated that most of the key functions can be learned in a four-to-six hour introductory session. Those field offices that utilized the System II for data compilation seem very supportive of its capabilities.

The System II is not too dissimilar from earlier machine oriented photo image interpretation/analysis systems. However, the current costs at $50,000 per unit, the need to have high scene contrasts among features in the scene to differentiate among them, the variable topogra-

phy of much of the Western public lands which would lead to high machine interpretation error, and the influences of aerial photo taking and processing causing different image characteristics of the same item precludes consideration of purchase of the units. The Bureau should continue to evaluate the technology in case there might be some future significant breakthrough that would be valuable to the Bureau.

Arizona

Individuals contacted during the Arizona visit included personnel from the State Office and from the Safford, Phoenix, and Arizona Strip Districts. A majority of the time was devoted to discussing the Applications System Verification Test of the Arizona Strip and the Black Canyon Landsat Project.

In general, Landsat with its digital image processing procedures and products produced by the Denver Service Center or elsewhere, did not provide managers or resources specialists the kinds of information needed for project plans. In some instances, as occurred in Idaho, Landsat provided some acceptable information but only if large amounts of ancillary information, such as maps of seasonal livestock ranges or seasonal wildlife ranges, were integrated with the Landsat data and corrections were made of the maps that were beyond the information content of the Landsat data. However, it was stated, by some Soil Scientists and Resource Specialists, that where vegetation surface cover was less than 20-30 percent as in some desert areas, soil associations based on soil surface color could be mapped which would be helpful for soil surveys. Some interviewees believed that Landsat data could be useful

for detecting public land infringements such as agriculture or surface mining.

During the conduct of the Arizona Applications System Verification Test, accuracy assessments were made of some of the land classification products and apparent agreement reached on classification acceptability. Subsequently, later Landsat projects, for example, the Arizona Black Canyon Project, had minimum project planning including allowance for accuracy assessments. This led to accepting products without accuracy assessments only to be learned later, by field personnel, that products were unacceptable because of major classification errors. This led to disillusionment by potential users of Landsat information on its capabilities to acceptably classify landscapes. Also, it was learned that in many instances, no cost comparisons were made between Landsat and other more conventional ways for mapping vegetation and apparent land use, especially relative to the various levels of detail acquired by the different methods.

There was interest in Landsat from the standpoint that the data are digital and, consequently, would allow direct entry into a geographic information system. This is not a direct process, however, and work needs to be done to determine the relationships between remote sensing data and geographic information systems.

Some work has been done in the Arizona Strip on use of Advanced Very High Resolution Radiometer (AVHRR) data from the NOAA satellite. According to some, the results of mapping vegetation with the AVHRR data provides acceptable information for fire management purposes. The Bureau is currently making a more thorough evaluation of AVHRR data for

fire fuels mapping.

Use of aerial photographs has been varied. In some instances, relatively large scale (1:12,000) color infrared has been used to evaluate stream channelization and some changes in riparian ecosystems. Some larger scale color infrared photographs have been used to evaluate riparian situations, apparently following procedures developed at the Denver Service Center. Also, in one instance, aerial photographs had been used to provide a record over time of general change in vegetation, presumably caused by grazing. Many consider aerial photographs to be an important element of resource inventory and monitoring. However, the photographs were not being used most effectively because of lack of training and lack of quality photographs.

Information needs for resource monitoring/inventory were stated to be basically land (vegetation) classification and measurement of plant communities principally by frequency and cover, basal and foliar, of all species. However, the classification of plant communities among Districts was not synonymous, which could lead to incompatibility if attempts are made to merge the data. Plant frequency is estimated either by pace transects or using a single plot size. This is inappropriate since each species has its own plot size for frequency estimates depending on density and distribution of the species. In addition, plant vigor and soil stability information are collected for monitoring purposes. It was not learned if information for individual species had been attempted to be secured by use of aerial photographs, even though some plant characteristics can be estimated from appropriate aerial photographs.

New Mexico

Individuals contacted during the New Mexico visit included personnel from the State Office and from the Farmington, Taos, and Rio Puerco Area offices. Most recent remote sensing work in New Mexico has dealt with Landsat for assisting in resource inventory and monitoring including Environment Impact Statements. The work has been done with the assistance of the Denver Service Center.

In general, managers and specialists who have worked with Landsat imagery and products reached conclusions similar to those in Arizona and Idaho. It was a consensus that Landsat products provided little information that was not available from other sources for resource inventory and/or monitoring purposes; the reasonably acceptable products were not of sufficient detail for specific management planning. In some instances, some acceptable information was developed provided sufficient ancillary data were merged with the Landsat products. However, as one interviewee inferred, "Why use Landsat data if more and better information (more and better not defined) can be obtained at the same or less cost using high quality 1:24,000 scale aerial photographs?". In some instances, it was believed that Landsat information did provide some preliminary assistance for forestry planning, provided topographic information was merged with Landsat information. For example, there was general acceptance of the Landsat classification of woodland (pinyon-juniper). With topographic (elevation) information, decisions could be made on the feasibility of intensive woodland management, e.g. intensive fire wood management. Also it was a consensus that Landsat was an acceptable Level II land cover classifier. In some instances, this

level of classification was felt to be useful in the broad resource planning process.

There has been little recent work done with aerial photographs. There has been some work done with large scale, 1:1,000-1:4,000, aerial photographs for riparian ecosystem evaluation, similar to that done in Arizona and Idaho, but this has been minimal because of difficulty in acquiring the photography and the lack of a committed aerial photo acquisition program. However, it was stated by many that aerial photographs would continue to be the major remote sensing medium as an asset to resource planning and management.

There were misconceptions of the meaning of remote sensing. To some, remote sensing meant Landsat only. Also there was a misconception of an apparent high utility of Landsat data for direct entry to a geographic information system. These ideas are predicated and perpetuated by a lack of remote sensing training and awareness.

There was a concern by some, and an apparent lack of concern by others, on the fate of data and remote sensing material, such as aerial photographs, after a project was completed or a problem solved. There seemed to be no specific plan for information storage and retrieval in the office. This could be unfortunate because the basis of monitoring is change over time and without baseline records, evaluation of change would be difficult or impossible.

There was no consistent set of information needs and requirements among the field units visited in New Mexico. There were some general similarities, for example, in that all units visited identified the need

for information on range condition and trend but the specific data elements to use for computation of range condition and trend varied among the units. Similarly, land classification was somewhat dissimilar among the units visited even though they all used a four level hierarchy.

A high degree of enthusiasm for applications of remote sensing and other new technologies, particularly geographic information systems, to assist in resource planning and management was expressed by all units visited in New Mexico. However, pragmatism existed since it was stated that, whatever technique was developed, it needed to be fully understood and accepted by the resource specialists and public land users. This emphasizes the requirement for techniques developers to involve specialists and users from the outset of developmental activities to keep them informed of progress.

California

Although not originally planned, a member of the review team visited the California Desert District, Riverside. The need for this visit was identified after the review of the questionnaire responses. The primary purpose of the visit was to obtain information on a resource inventory, conducted in the late 1970's, of the California Desert Conservation Area using Landsat data and large scale (1:1,000) color aerial photography.

The methodology consisted of using Landsat data for land cover classification of a 25 million acre area. The Jet Propulsion Laboratory, Pasadena, California, did the data processing. Twenty eight spec-

tral classes were related to range forage production data obtained by photo interpretation of large scale (1:1,000) aerial photography. Forage allocations were made and grazing decisions were issued based on this data.

A unique feature of this project was the photo interpretation and analysis procedure for estimating herbage production. To clearly describe the procedure used to estimate production of perennial plants, the following is presented from the report "Resource inventory techniques used in the California Desert Conservation Area" prepared jointly by the Jet Propulsion Laboratory and the Bureau of Land Management (McLeod and Johnson 1981).

"LOW LEVEL AERIAL TRANSECT ANALYSIS AND INTERPRETATION

Large scale aerial photos were used to estimate the biomass and production of perennial plants for selected transects throughout the desert. The goal in the production/ biomass estimation of perennial plants was to determine range carrying capacity for livestock in designated allotments. The ephemeral component of forage productions i.e., winter and summer annuals, cannot be estimated on a yearly basis due to the extreme variability of moisture and temperature.

In order to arrive at a quantitative interpretation of the Landsat classification for the purpose of estimating range carrying capacity, it was necessary to extract several types of botanical data from the photo transects. These data included:

1. Species composition--a list of species that were present in the transect;
2. The amount of each species present in terms of percent ground cover;
3. The height of the species present;
4. Volume and inferred density of the species present, derived from the cover and height.

It was important to insure the accuracy of species identification in order to relate production to biomass. Extensive use was made of field information regarding what plants were present for transects that had been visited. Height was determined from stereo viewing, but was usually done in a relative sense rather than an absolute sense owing to some variability in the scale of the transects. By using well known plants as indicators, the height could be estimated rather closely.

With the initial extraction of this data from the transects, it was possible to obtain a value of Standing Biomass in kilograms per hectares (kg/ha). Biomass was determined for the transects through volume measurements related to volume density equations obtained for a spectrum of indicator species. However, the biomass values by themselves are not directly usable for determining carrying capacity for livestock. Considerations for both production and palatability to livestock are also important. The task then became one of determining the relationships among biomass, production and palatability.

In the early 1970's, the International Biological Program, Desert Biome portion exerted considerable effort in making measurements of various types on desert plants. Some of the research reported on the relationship between biomass and production for various species. Biomass and production are considered to be positively correlated as a function of woodiness. With the production to biomass ratios established for species within the transects a value of Total Production in kg/ha could be ascribed. This value is an estimate of new growth for a year. Taking into account livestock grazing preferences and consulting palatability tables, the production for plant species grazed by livestock was estimated in kg/ha and this value reflected Total Forage Production. After deciding which species were forage producers, proper use factors were assigned each species. The proper use factor, when included, defines the amount of forage that can be consumed by livestock and yet preserve plant production in a sustained yield basis. Palatability and proper use tables have historically been developed over the years by the BLM, particularly, the Riverside District office, Las Vegas District office and the Kingman, Arizona District office. The proper use factor for species was multiplied by the Total Forage Production for species to obtain values of Renewable Forage Production."

This procedure was discussed with the BLM employee responsible for the photo interpretation. The individual felt that the high resolution of the large scale photography permitted high accuracy identification of individual plant species. The photography involved the use of 9 x 9-in. format

Kodak Special Order 394 natural color film at an approximate scale of 1:1,000. Five hundred sites were photographed, although only 200-225 were interpreted. A series of five stereo photos per site were acquired for interpretation of 40 acres per site. Fifty to 75 of these sites were field-visited to verify delineations and gather additional data.

In summary, the California Desert Conservation Area rangeland inventory procedure using Landsat and 1:1,000 scale color aerial photos provided data that were used to make management decisions. However, only those individuals who were involved during the process and familiar with the data will use the data routinely. It appears that a possible methodology for monitoring desert vegetation may have been demonstrated.

List of Findings

1. A high level of enthusiasm and professionalism was evidenced by Bureau of Land Management personnel in the development and implementation of new and improved techniques which would assist in coping with complex management decisions.

2. Many Bureau managers and specialists expressed serious concern with their capabilities to perform the apparent level of rangeland monitoring required, considering presently available or foreseeable resources. Consequently, they are extremely interested in applying new techniques including remote sensing to assist in accomplishing their requirements.

3. The Public Rangelands Improvement Act (PRIA) requires that the Bureau prepare information on range condition and trend. This

requirement, and the need to develop and complete environmental statements has increased emphasis on rangeland monitoring, with an apparent decrease in activities for rangeland inventory. The decentralized nature of the Bureau has allowed field units to independently define their information needs and develop their their own procedures to meet that PRIA and other requirements for monitoring. This has resulted in a general discontinuity of information requirements among field units and development of procedures to obtain required information. However, frequency of individual plant species within plant communities alone or in combination with other species attributes within the community is the most common attribute.

4. Current literature on rangeland remote sensing indicates that some identified information requirements are observable and measurable by remote sensing and some requirements cannot be obtained using remote sensing. Also, current literature indicates that inferred "off-the-shelf" technology has been insufficiently documented for immediate application; some applications procedures need to be prepared.

5. There is a general lack of adequate training and awareness of remote sensing techniques and applications at all management and specialist levels.

6. There is a lack of clear direction within the Bureau on goals and objectives to recognize opportunities for using remote sensing for range management activities. This finding is related to Finding 3 and the lack of a minimum set of data elements and information requirements

for renewable resource monitoring and inventory.

7. Generally, there was a lack of detailed project planning prior to initiation of Landsat and other remote sensing application demonstrations. Consequently, unsatisfactory communication, understanding, and agreement on project goals, objectives and expected products developed.

8. The apparently acceptable Level II land cover classifications attainable from analysis of Landsat multispectral data were generally not of sufficient detail to satisfy Bureau rangeland monitoring and management requirements. Level IV land cover classification is the minimum necessary for detailed project planning. Level III may have some applicability for generalized project planning.

9. Accuracy assessments of Landsat products were generally not accomplished in favor of increasing project area coverage.

10. There is an assumption among many Bureau personnel that, since Landsat data is in digital form, its use for vegetation (land cover) classification results is an optimum vegetation classification for incorporation into a geographic information system. This assumption was made apparently regardless of level of accuracy and/or level of classification.

11. The Denver Service Center image processing computer system requires upgrading and significant maintenance to continue internal Landsat or other digital remote sensing data processing capabilities by the Center.

12. There has been little effort by the Denver Service Center to evaluate or assist in implementation of promising aerial photograph techniques for range management monitoring or inventory. Part of the reason for this has been emphasis on evaluation of Landsat imagery for range management and other purposes. Consequently, some field offices have done these evaluations independently and with little coordination with the Denver Service Center or other field units.

13. There is a lack of adequate field office photointerpretation equipment and material.

14. The Denver Service Center has maintained excellent rapport with several centers of remote sensing expertise. The Center should continue and expand this activity.

15. Procedures for storage and retrieval of aerial photographs and other supporting data about renewable resources monitoring and inventory is lacking.

RECOMMENDATIONS

Establish Remote Sensing Program

Resource managers at all levels in the Bureau of Land Management are, in general, aware that available resources for the foreseeable future are

likely to be inadequate to accomplish essential resource monitoring activities by conventional ground methods. A considerable basis already exists for consideration of remote sensing as a cost-effective monitoring supplement coupled with ground data range resource assessment. For example, tree and shrub species can be acceptably identified with appropriate large scale color infrared aerial photographs and, with sampling, can provide estimates of cover, density, and perhaps frequency (See Table 2). The high degree of professionalism, enthusiasm, and recent remote sensing experience at State, District and Resource Area offices presents an excellent opportunity to carefully test and evaluate promising remote sensing techniques, especially those using aerial photographs, for renewable resource assessment and monitoring.

Recommendation Number 1. The Bureau of Land Management, through the Denver Service Center Remote Sensing Staff, should fully commit to a remote sensing program, with emphasis on aerial photographic techniques for rangeland and other resources assessment and monitoring. The program should consist of the following basic elements.

- Maintain a state-of-the-art familiarity with current developments in remote sensing techniques and application.

- Maintain suitable internal capabilities to evaluate and assist in implementing at field offices appropriate remote sensing technology.

- Continue to seek, establish and maintain cooperative working relationships with centers of remote sensing expertise.

- Support and supervise external applications studies designed to bring useful new remote sensing technology into range management and other resource systems.

Develop Aerial Photography Applications Program

The use of aerial photographs for Bureau range resource inventory and monitoring has been de-emphasized during the last 6 to 8 years in order to make evaluations of Landsat data for those purposes. Nevertheless, developmental work with large and small-format aerial photography applications have occurred, mostly at field offices. Types of applications accomplished, but not fully documented, or in progress and which are related to both inventory and monitoring include riparian habitat evaluation, range vegetation trend analysis, wildlife habitat classification, and watershed management (e.g. water quality, soil erosion, stream quality for fisheries, and plant cover effects and changes on fisheries and wildlife).

Recommendation Number 2. Develop a vigorous aerial photography applications program which includes:

- The Denver Service Center should continue to assist the Bureau state organizations, when requested, in the specification, acquisition and application of medium scale (1:12,000 - 1:36,000) large format resource photography.

- Intensive evaluation of NHAP (National High Altitude Aerial Photography Program) photography capabilities for Bureau resource management applications is needed. Also, the Bureau should continue supporting the Program because of is sequential nature (reflights

at 4-5 year intervals), low unit cost and high photographic resolution. Closer involvement by the Bureau in future NHAP program planning should occur and could result in more effective timing and selection of location of overflights to be more responsive to Bureau resource management needs.

- Evaluate the capabilities of large scale (1:500 - 1:3,000 and up to 1:10,000) large and small format aerial photography to supplement existing range monitoring systems. Develop procedures and methodology for field use.

- Fully document, by widely distributed formal reports, results of all testing and evaluation projects.

Provide Remote Sensing Training

Despite the proven importance of remote sensing as a practical cost effective resource management and monitoring tool, many colleges and universities no longer provide adequate practical remote sensing training. As a consequence, most major resource management agencies, including the Bureau, have been forced to develop and carry out their own training programs. This situation is not likely to improve. As a matter of fact, it appears to be worsening with the result that the responsibility of providing remote sensing training will increasingly be the responsibility of the management agencies.

Currently, many key natural resources staff personnel, unit managers, resource managers, professionals, and technicians have an inadequate comprehension of remote sensing. A minimum level of remote sensing under-

standing including use of aerial photography and digital imagery is required to improve internal capability to apply remote sensing techniques to renewable resource management actions and to recognize the limitations of remote sensing for some applications.

Recommendation Number 3. The Bureau, through the Denver Service Center, should maintain and enhance remote sensing training programs by providing:

- Basic training in aerial photo interpretation and photogrammetry.

- Basic training in the understanding and proper application of the different kinds of remote sensing (e.g. aerial photography, multi-spectral sensing, radar and radiometers).

- When required, provide training in appropriate remote sensing techniques for discipline-oriented applications (e.g. range, wildlife, hydrology, forestry) in which field resource specialists become aware of and have the opportunity to apply specific techniques for specific purposes.

- Provide guidance in the selection of appropriate field level remote sensing analysis equipment and materials.

- Provide awareness training for managers responsible for resource management programs.

Digital Remote Sensing Data Analysis

Capabilities and limitations of conventional Landsat multispectral

scanner data (4-band, 80-meter resolution) have been adequately defined. Generally, land cover classification is accomplished, at a maximum, to Level II (e.g., Deciduous Forest, Shortgrass Grassland, Evergreen Shrubland). Such information is of minimum value for Bureau rangeland management applications. Information of potentially greater value is available from other sources such as aerial photography and archived data files. However, the application values of Landsat Thematic Mapper data (7-band, 30-meter resolution) have yet to be defined. Higher resolution data from future satellite remote sensing systems can be expected and will require evaluation.

Recommendation Number 4. The Bureau, through the Denver Service Center, should maintain a minimal but viable internal capability for satellite digital remote sensing data analysis.

- Conventional Landsat image analyses capabilities should be maintained at a level sufficient to meet limited, but important, user requirements (e.g., agricultural infringement in rangelands, wildfire mapping, dramatic land surface disturbances such as mining).

- Internal evaluation capabilities of current and future satellite remote sensing digital data which have high probability of practical utility for rangeland management activities should be maintained.

Remote Sensing - Geographic Information Systems

The Bureau is working aggressively toward development and implementation of Geographic Information System (GIS) technology at the field

offices. A critical data theme for a GIS is an accurate current vegetation map suited to management needs. Digital analysis of conventional Landsat data generally provides inadequate detail for range management project use. Nevertheless, the fact that Landsat is in digital form has led to the misconception that it is automatically the optimum vegetation data source for direct inclusion into a GIS.

Recommendation Number 5. The Bureau, through the Denver Service Center, should make a critical review and evaluation of the relationships between remote sensing digital image processing and products and data entry into a GIS. The Service Center should evaluate all potential sources of remotely sensed vegetation information for inclusion into a GIS. Source selection should be based upon data resolution requirements, accuracy, needs, and cost.

Remote Sensing Coordination

Establishment of an active and effective remote sensing program within the Bureau requires the continued interest, support, and direct involvement of Bureau Washington Office, State, District and Resource Area personnel. A key component of this program exists in the form of designated Remote Sensing Coordinators at State and, in some cases, District and Area offices. Currently, the remote sensing coordinator function is usually combined with other responsibilities such as Geographic Information Systems development and coordination.

Recommendation Number 6. The Bureau should continue active support of the Remote Sensing Coordinator Concept.

- Personnel assigned as Remote Sensing Coordinators must be technically qualified and highly motivated in applications of remote sensing and have an understanding of renewable natural resources. While initially a position combining remote sensing and other responsibilities appears logical, each of these functions could develop into full-time responsibilities, often with separate and distinct technical capability requirements.

- A Remote Sensing Resource Advisory Team comprised of the State, Denver Service Center, and Washington Office Remote Sensing Coordinators, and including resource specialists, should be established. The Team should be chaired by the Chief, Branch of Remote Sensing, Denver Service Center.

  The responsibilities of the Team should include:

  - Assistance in development and prioritization of Bureau and Denver Service Center remote sensing programs.

  - Upon request, review internal and external remote sensing proposals to assure technical competency, avoid duplication and assure compliance with user requirements.

  - Upon request, review Bureau remote sensing projects. Establish, initiate and maintain a remote sensing technology transfer program.

<u>Information Needs and Large Scale Photography</u>

The Bureau has not established a minimum set of data and information

requirements and standards for monitoring and inventorying renewable natural resources. This has led to a general discontinuity of information requirements since each field unit has independently defined data and information requirements. This has resulted in a proliferation of data and data collection procedures which may or may not be compatible. Also, there are no easily adaptable range remote sensing techniques that can be immediately implemented without preparing and documenting applications procedures. This is because of the relationship of remote sensing research and development to geographic locations and technology transfer; a proven technique for one location needs to be verified at other locations. As a result of initiatives at field offices, several opportunities exist, for example in California, Oregon, Idaho, and Arizona, to evaluate the application of remote sensing data for monitoring. At these locations, recent (4-6 years) large scale aerial photography and supporting ground data exist. Evaluation and documentation of the applicability of the remote sensing technique used to obtain specific kinds of data to supplement range monitoring procedures needs to be conducted.

Recommendation Number 7. The Bureau, through the Denver Service Center and with the Branch of Remote Sensing and the Division of Resources Systems collaborating, should define a minimum set of data elements and information requirements to assure compatibility of data collection and data aggregation. Also, these Units should collaborate in testing and evaluating large and small format aerial photography to supplement range monitoring systems. Appropriate remote sensing and resource field specialists should provide as much assistance as possible. Procedures and applications for field operations should be developed. The need to secure con-

tractual assistance should be considered during development of the evaluation plan, data analysis, and preparation of technical procedures and instructions. Conclusion of this work, within three years, will provide an additional basis for future Bureau remote sensing programs in support of rangeland and other renewable resource management programs.

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APPENDIX I

Task Order No. 1, Cooperative Agreement YA-551-CA4-340003

Cooperative Agreement
Between the
Department of the Interior
Bureau of Land Management/Denver Service Center (BLM)
and
Colorado State University (CSU)

Agreement No. YA-551-CA4-340003

Task Order No. 1

A. Statement of Work

General - The Bureau of Land Management and Colorado State University will review and evaluate the Bureau's rangeland and related renewable resource remote sensing activities to determine their effectiveness for assisting in land management planning and natural resources programs. This review and evaluation will provide data and information from which long-range plans can be developed for full utilization of state-of-the-art and emerging remote sensing technologies, and for the development of graduate and undergraduate courses in resource management applications of remote sensing methods.

A final report which will summarize results of the evaluation, make recommendations, and develop guidelines for incorporating state-of-the-art and developing remote sensing technologies into the remote sensing programs of the Bureau will also be prepared.

The following are specific tasks that are to be performed:

Task 1 - Review and Evaluation of BLM Renewable Resource Remote Sensing Activities and Requirements

Phase 1: CSU and the BLM representatives will meet at Building 50 on the Denver Federal Center to review requirements of this project. The group will develop standards and guidelines that will serve as the basis for the formal review and evaluation of BLM remote sensing activities and requirements. During this phase, BLM remote sensing operations at the Denver Service Center will also be evaluated.

Phase 1 will be completed within 14 days of the date of execution of this Task Order.

Phase 2: A field review and evaluation of BLM rangeland and renewable resources remote sensing activities will be accomplished. CSU and BLM representatives will jointly conduct the field reviews. Field offices in at least three of the following states will be visited: Wyoming, Idaho, Alaska, Oregon, Colorado, Utah, Montana, Arizona, New Mexico, California, and Nevada. The BLM Project Manager and the CSU Team Leader will discuss this issue and make the selections after initiation of this Task Order.

One week will be spent at each location. BLM resource specialists and managers will be interviewed. The standards and guidelines developed in Phase 1 will be utilized to evaluate the methodologies and results of the remote sensing work.

Since only a few states can be visited during this evaluation, a questionnaire will be prepared by BLM to solicit additional data from other BLM organizations. Responses from this questionnaire will be incorporated into the evaluation.

Phase 2 will be completed within 90 days of the date of execution of this Task Order.

Task II - Reports

A summary written report will be prepared by the participants. This report will include the following components:

1. Results of the field review of BLM remote sensing activities.

2. An evaluation of recent and ongoing BLM rangeland and related resource remote sensing activities in relation to the state-of-the-art. Relevant and current published information on applications of remote sensing for rangeland inventory, rangeland evaluation, and rangeland monitoring will be included in the final report as literature review.

3. Recommendations and detailed state-of-the-art guidelines from which the Bureau can: (a) implement current remote sensing methodologies, and (b) develop a long term strategy that includes development work to incorporate remote sensing procedures into its renewable resource activities.

Task II will be completed and delivered to the BLM Project Manager within 120 days of the date of execution of this Task Order.

Additional reports or professional publications resulting from this project work that are prepared by any of the participants will be encouraged.

B. Performance Schedule and Delivery of Data

1. Schedule for Performance

Task No.	Due (days after execution of Task Order)
Task I - Review and Evaluation	
Phase I	14
Phase II	90
Task II - Final Report	120

2. Delivery of Data - Data called for under this Task Order shall be delivered prepaid and shall reference the Task Order number to:

Bureau of Land Management
Attention: Fred Batson
Denver Service Center, D-442
Denver Federal Center, Bldg. 50
Denver Colorado 80225

A copy of the transmittal letter forwarding documents required herein shall be forwarded to the contracting officer.

C. The Not-to-Exceed (NTE) amount for this Task Order is $50,000.

D. The cost proposal (Enclosure No. 1) for this effort is hereby incorporated.

IN WITNESS THEREOF, THE PARTIES HERETO HAVE CAUSED THIS Agreement to be executed.

Colorado State University

Name James F. Brown

James F. Brown
Assistant V.P. for Research

Title

Date 8/13/84

Bureau of Land Management

Name

Contracting Officer

Title

Date 8-14-84

APPENDIX II

Field Visit Itinerary and Persons Contacted

Denver Service Center Remote Sensing Review
August 15-16, 1984; September 28, 1984

Wednesday, August 15, 1984

8:30 a.m. - Get Together (Visit with Denny Parker/Del Vail)

9:30 a.m. - D-470 Discussions (Rangeland Inventory and Monitoring)

Alan Strobel
Ron Clark
Kris Eshelman

LUNCH

1:00 p.m. - Soils Discussion (Jim Stone, D-470)
1:30 p.m. - Hydrology Discussion (D-470)
2:00 p.m. - Remote Sensing Training Discussion (Wally Crisco, D 442)
3:00 p.m. - TGS Discussion (Gregg Johnson)

Thursday, August 16, 1984

8:00 a.m. - Project Discussion (Digital Image Analysis)
(Ed Work/Laura Hall, D-440)

10:00 a.m. - Rangeland Inventory Discussion (Bob Wagner, D-470)

10:45 a.m. - Wildlife Discussion (Paul Cuplin, D-470)

LUNCH

1:00 p.m. - Team Discussions: Team summarizes DSC activities and develops strategy for field visits.

Team firms up travel plans for Idaho, Arizona and New Mexico.

Friday, September 28, 1984

10:00 a.m. - 12:00 noon — Information Needs (Baker)

1:00 p.m. - 3:00 p.m. — Taos Project (Foster)

DSC Personnel Contacted

Delmar D. Vail	Director
H. Dennison Parker	Assistant Director, Technical and Scientific Systems
Allen Strobel	Branch Chief, Biological Resources (D-470)
Kris Eshelman	Range Conservationist (D-470)
Ron Clark	Branch Chief, Physical Resources (D-470)
Jim Stone	Soil Scientist (D-470)
Eric Janes	Hydrologist (D-470)
Wallace Crisco	Remote Sensing Staff (D-440)
Gregg Johnson	Project Manager, Technicolor Government Services
Ed Work	Remote Sensing Staff (D-440)
Laura Hall	Natural Resource Specialist (D-440)
Paul Cuplin	Fishery Biologist (D-470)
John Baker	Chief, Division of Resource Systems (D-470)
John Foster	Natural Resource Specialist (D-440)

Idaho Remote Sensing Review
August 27-31, 1984

AGENDA

August 27	P.M.	ISO Remote Sensing Applications, Program Review, Etc. Idaho State Office	Harrison Mitchell Stevens
August 28	A.M.	ASVT and Cascade Landsat Projects Boise District	Seiner Rush
	P.M.	Vale District, Oregon 9" CIR Riparian Study Idaho State Office	Findley Krause
August 29	A.M.	LARS Project Soil-Veg Inventory - Monument EIS Idaho State Office	Harrison
		Contractor's Perspective Idaho Image Analysis Facility	Anderson
August 30	A.M.	Little Wood Project (9:30) Shoshone District	Rich Carter
	P.M.	Riparian Monitoring (2:00) Burley District	K. Koch
		Soda Springs Landsat MSS Land Cover Project Burley District	Harrison McFarling
August 31		9:00 A.M. - Al Logosz (Branch Chief - 930) 10:00 A.M. - Karl Gephart (Hydrologist - 930)	

List of Idaho Personnel Interviewed

Name	Position
State Office	
Clair Whitlock	State Director
Harold Ramsbacher	Deputy State Director - Resources
Al Logosz	Branch Chief, Range and Wildlife
Doug Harrison	Remote Sensing Coordinator
Bob Mitchell	Range Specialist
Karl Gephart	Hydrologist
Gary Stevens	Cartographic Section Chief
Boise District	
Dick Geier	Cascade Area Manager
Bill Weigand	Chief, PEA
Bill Hagdorn	Planning Coordinator
Tom Seiner	ADP/RS Coordinator
Ted Milesnick	RMP/EIS Team Leader
Bill Rush	Natural Resource Specialist
Shoshone District	
Chuck Haszier	District Manager
Irwin Cowley	Monument Area Manager
Bob Cordell	Bennet Hill Area Manager
Jon Idso	ADM - Resources
Joe Carter	Range Conservationist
Larry Mangen	Wildlife Biologist
Terrell Rich	Wildlife Biologist
Burley District	
Kirk Koch	Hydrologist
Idaho Falls District	
Russ McFarling	

Vale District, Oregon

(Traveled to Boise to discuss riparian photography with the team)

Name	Position
Gene Findley	Range Specialist
Mike Crouse	Fisheries Biologist

Arizona Remote Sensing Review
September 10-12, 1984

Itinerary

September 10, p.m.	Arizona State Office
	Safford District
	Phoenix District
September 11, a.m.	Phoenix District
p.m.	Travel to St. George, UT,
	and AZ Strip District
September 12, a.m.-p.m.	Arizona Strip District

Arizona Personnel Contacted

State Office

George Ramey	State Range Conservationist
Steven Wing	State Remote Sensing Coordinator
Bob Raudabush	Soil Scientist
Carol Hamilton	Branch Chief, Resources

Safford District

Les Rosenkranze	District Manager

Phoenix District

Barry Stallings	Assistant District Manager
Ted Cordery	District Biologist
Bob Mitchell	District Range Conservationist
Dan McGlothlin	District Hydrologist
Tom Craft	District Soil Scientist

Arizona Strip District

Bill Lamb	District Manager
Julian Anderson	Chief, Resources
Glenn Joki	Fire Management Officer
Kenneth Moore	Planning and Environmental Coordinator
L. D. Walker	Range Conservationist
Lee Hughes	District Range Conservationist
Ron Ray	ADP Coordinator
Bob Smith	Natural Resource Specialist
Chris Horyza	Range Conservationist

New Mexico Remote Sensing Review
October 15-19, 1984

Itinerary

September 15, p.m.	Albuquerque - Wildlife Habitat Classification Travel to Farmington
September 16	Farmington Area Office
September 17	Taos Area Office
September 18	New Mexico State Office
September 19	Rio Puerco Area Office

New Mexico Personnel Contacted

State Office

Monte Jordan	Associate State Director
John A. Dimas	Scientific Systems and State Remote Sensing Coordinator
Ed Roberts	Chief, Information Services
Dave Jones	Deputy State Director, Lands and Renewable Resources
Verlya Soloder	State Soil Scientist
Herb Garn	Hydrologist
Richard Kerr	Wildlife Biologist (Ret), DSC (Interview in Albuquerque)

Farmington Area Office

Mat Millenbauch	Area Manager
Stan McKee	Assistant Area Manager
Arlan Hiner	Biological Resources
Dana Shuford	Natural Resource Specialist
Mike Candalleria	Range Conservationist

Taos Area Office

Richard Neimeyer	Area Manager
Bill Holscheimer	Geologist
Robert Martinez	Range Conservationist
Mike O'Neill	Supervisor, Natural Resources Staff
Buff Jebsen	Forester

Rio Puerco Area Office

Rich Hanks	Area Manager
Jim Turner	Area Geologist
Gene Tatum	Range Conservationist
Don Brewer	Wildlife Biologist
Susan Duffy	Student Assistant
Duane Vincent	Range Conservationist

California Remote Sensing Review
November 5, 1984

Itinerary

November 5	California Desert District Riverside

Personnel Contacted

Kathie Jewell	Physical Scientist, Remote Sensing/GIS Coordinator
Albert Endo	District Soil, Water and Air Specialist
Glenn Harris	Range Conservationist (Ridgecrest Resource Area)
Robin Krehr	Botanist (Indio Resource Area)
Larry Foreman	District Wildlife Biologist

APPENDIX III

Remote Sensing Questionnaires

United States Department of the Interior

BUREAU OF LAND MANAGEMENT
DENVER SERVICE CENTER
DENVER FEDERAL CENTER, BUILDING 50
DENVER, COLORADO 80225

IN REPLY REFER TO:

9673 SS00 (D-442)

Instruction Memorandum No. DSC-84-
Expiration Date 9/30/85

To: All State Directors

From: Service Center Director

Subject: Remote Sensing Questionnaires DD 08/31/84

The Washington Office and the BLM Rangeland Remote Sensing Task Force have requested that a review of the Bureau's remote sensing activities be conducted prior to the end of FY 84. The primary purposes of the review will be to (1) evaluate our remote sensing procedures compared to the state-of-the-art and (2) to identify techniques with potential for operational Bureau use. Particular emphasis will be placed on evaluating existing remote sensing techniques as they relate to rangeland inventory and monitoring procedures.

The review will consist of a limited number of field office visits this summer plus evaluation of written field office responses. The states selected for these visits have not yet been identified. We assure you that all efforts will be made by D-442 (Branch of Remote Sensing) to schedule these visits so as to create a minimum disruption of field office workloads.

Since only three or four field offices can be visited, we are soliciting additional input to the review via the attached questionnaires. Questionnaires No. 1, 2 and 3 have been developed for both managers and non-managers who have had some experience with remote sensing projects or applications. Their purposes are to obtain individuals' evaluations of the techniques used and the outputs produced. Questionnaire No. 4 was developed to solicit employees' (managers and non-managers) ideas about possible remote sensing applications they feel need to be evaluated.

To facilitate this effort, we request that your State Office Remote Sensing Coordinator assure that the appropriate State Office, District Office and Resource Area managers and non-managers have an opportunity to respond to the questionnaires. For purposes of this review, we are defining the term "remote sensing" to include all of the following: (1) automated or visual analysis of satellite imagery, (2) visual interpretation of large, medium or small scale aerial photography, and (3) application of additional techniques such as thermal IR, radar, laser, etc. Please assure that both formal remote sensing projects (i.e., Landsat analysis) and less formal in-state remote sensing applications (i.e., photo interpretation) are covered by the questionnaire responses.

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We request that Questionnaires No. 1 through 3 be filled out by appropriate personnel for each major remote sensing project or application that your state has been involved in since 1976. We recognize that changes in personnel will make this difficult for some of the previous work. If key personnel have transferred, please send the appropriate questionnaires to their new office so that they can be included in your submissions.

Questionnaire No. 4 should be answered by all employees (manager or non-manager, any level) willing to contribute. As stated previously, one of the goals of this review is to identify possible remote sensing applications that require further evaluation. We need your help and guidance in identifying those job elements or applications where remote sensing techniques may be useful so that we can develop a long-term strategy to evaluate and implement the proper techniques.

We request that the State Office Remote Sensing Coordinator not attempt to consolidate or summarize the responses. Please provide the questionniare responses to Service Center Director (D-442), on or before August 31, 1984. Direct any questions pertaining to the review or the questionnaires to Fred Batson, Chief, Branch of Remote Sensing (FTS 776-6376 or commercial 303-236-6376). We greatly appreciate your assistance in this effort and will provide you with copies of reports generated as a result of the remote sensing review. Thank you.

4 Enclosures
- Encl. 1 - Remote Sensing Questionnaire No. 1 (5 pp)
- Encl. 2 - Remote Sensing Questionnaire No. 2 (6 pp)
- Encl. 3 - Remote Sensing Questionnaire No. 3 (3 pp)
- Encl. 4 - Remote Sensing Questionnaire No. 4 (4 pp)

Distribution
WO (221) - 1
WO (730) - 1
D-245A - 1

REMOTE SENSING QUESTONNAIRE NO. 1

FOR

MANAGERS*

Topic: Evaluation of Previous and Ongoing Remote Sensing Projects or Applications (1976 to present)

*INSTRUCTIONS: The respondent should have direct familiarity with the remote sensing effort discussed. For purposes of this questionnaire, remote sensing techniques to be considered include: (1) automated or visual analysis of satellite imagery, (2) visual interpretation of large, medium or small scale aerial photography, and (3) other techniques (thermal IR, radar, etc.).

Please fill out a separate questionnaire for each remote sensing project or application. If the project involved the use of remotely sensed data for incorporation into a Geographic Information System (GIS), please respond only for the remote sensing component of the project.

Name and Position of Respondent: ______________________________

Name of Project or Type of Application: __________________________

Year Accomplished: _______________

Project Data

(If more space is required, attach additional notes.)

A. Description of remote sensing techniques used -

B. Who did the analysis or interpretations (i.e., DSC, State Office, District Office, contractor, etc.)?

C. What were the objectives of the remote sensing project?

1. Associated with rangeland inventory, monitoring or improvement work -
2. Objectives related to other activities (watershed, wildlife, minerals, etc.) -

D. Did the end products meet the stated objectives? How? If not, why?

1. Associated with rangeland inventory, monitoring or improvement work -
2. Associated with other activities -

E. Were the data or products used? How? If not, why?

1. Associated with rangeland inventory, monitoring or improvement work -
2. Associated with other activities -

F. Did the data affect management decisions? How?

1. Associated with rangeland management -
2. Associated with other activities -

G. Would you use these techniques for future similar projects? Why? Why not?

1. Associated with rangeland management -
2. Associated with other types of data needs -

H. In your opinion, are the techniques cost/manpower efficient as compared to more conventional procedures? Why? (Please be specific)

1. Associated with rangeland management -
2. Associated with other types of data needs -

I. Additional Comments -

REMOTE SENSING QUESTONNAIRE NO. 2

FOR

RESOURCE SPECIALISTS/PLANNERS DIRECTLY INVOLVED IN A PREVIOUS OR ONGOING REMOTE SENSING EFFORT*

Topic: Evaluation of Previous and Ongoing Remote Sensing Projects or Applications (1976 to present)

*INSTRUCTIONS: The respondent should have direct familiarity with the remote sensing effort discussed. For purposes of this questionnaire, remote sensing techniques to be considered include: (1) automated or visual analysis of satellite imagery, (2) visual interpretation of large, medium or small scale aerial photography, and (3) other techniques (thermal IR, radar, etc.).

Please fill out a separate questionnaire for each remote sensing project or application. If the project involved the use of remotely sensed data for incorporation into a Geographic Information System (GIS), please respond only for the remote sensing component of the project.

Name and Position of Respondent: ______________________________

Name of Project or Type of Application: ______________________________

Year Accomplished: ______________

Project Data

(If more space is required, attach additional notes.)

A. Description of remote sensing techniques used -

B. Who did the analysis or interpretations (i.e., DSC, State Office, District Office, contractor, etc.)?

C. What were the objectives of the remote sensing project?

   1. Associated with rangeland inventory, monitoring or improvment work -
   2. Objectives related to other activities (watershed, wildlife, minerals, etc.) -

D. Did the end products meet the stated objectives? How? If not, why?

   1. Associated with rangeland inventory, monitoring or improvement work -
   2. Associated with other activities -

E. Were the data or products used? How? If not, why?

   1. Associated with rangeland inventory, monitoring or improvement work -
   2. Associated with other activities -

F. Did the data affect management decisions? How?

   1. Associated with rangeland management -
   2. Associated with other activities -

G. Would you use these techniques for future similar projects? Why? Why not?

   1. Associated with rangeland management -
   2. Associated with other types of data needs -

H. In your opinion, are the techniques cost/manpower efficient as compared to more conventional procedures? Why? (Please be specific)

   1. Associated with rangeland management -
   2. Associated with other types of data needs -

I. Have the outputs proven to be acceptable to fellow employees in accomplishing their jobs? How? If not, why?

   1. Associated with rangeland management -
   2. Associated with other types of data needs or activity planning -

J. Additional Comments -

REMOTE SENSING QUESTONNAIRE NO. 3

FOR

RESOURCE SPECIALISTS NOT INVOLVED DIRECTLY IN A PREVIOUS OR ONGOING REMOTE SENSING EFFORT, BUT WITH KNOWLEDGE OF AND EXPERIENCE WITH THE OUTPUTS*

Topic: Evaluation of Previous and Ongoing Remote Sensing Projects or Applications (1976 to present)

*INSTRUCTIONS: For purposes of this questionnaire, remote sensing techniques to be considered include: (1) automated or visual analysis of satellite imagery, (2) visual interpretation of large, medium or small scale aerial photography, and (3) other techniques (thermal IR, radar, etc.).

Please fill out a separate questionnaire for each remote sensing project or application. If the project involved the use of remotely sensed data for incorporation into a Geographic Information System (GIS), please respond only for the remote sensing component of the project.

Name and Position of Respondent: ____________________

Name of Project or Type of Application: ____________________

Year Accomplished: ____________

Project Data

(If more space is required, attach additional notes.)

A. Description of remote sensing techniques used -

B. Were the data or products acceptable and useful to you or your associates? How? If not, why?

   1. Associated with rangeland inventory, monitoring or improvement work -
   2. Associated with other activities -

C. Would you use these techniques for future similar projects? Why? Why not?

   1. Associated with rangeland management -
   2. Associated with other types of data needs -

D. In your opinion, are the techniques cost/manpower efficient as compared to more conventional procedures? Why? (Please be specific)

   1. Associated with rangeland management -
   2. Associated with other types of data needs -

E. Additional Comments -

REMOTE SENSING QUESTONNAIRE NO. 4
FOR
MANAGERS AND NON-MANAGERS

Topic: Remote Sensing Applications Requiring Further Evaluation*

*NOTE: For purposes of this questionnaire, remote sensing techniques to be considered include: (1) automated or visual analysis of satellite imagery, (2) visual interpretation of large, medium or small scale aerial photography, and (3) other techniques (thermal IR, radar, etc.).

(If more space is required, attach additional notes.)

Activity	Name of Respondent	Description of Application
1. Range Management:		
2. Soil, Water and Air Management:		
3. Wildlife Management:		
4. Forest Management:		
5. Wild Horse and Burro Management:		
6. Recreation/Cultural/Wilderness:		
7. Realty:		
8. Planning:		
9. Energy and Minerals:		
10. Fire:		
11. Law Enforcement:		
12. Engineering:		
13. Mapping:		
14. Other:		

APPENDIX IV

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APPENDIX V

Summaries of State Responses to Remote Sensing Questionnaires

A. State: Alaska
Number of Responses: 9

1. Photography Applications

Response described use of photography to delineate meander lines for use in the land conveyance program. Procedure is accepted by State government and others as legitimate method to establish these lines.

2. Digital Processing Applications

Alaska has undertaken several in-house projects using Landsat. The responses would indicate that most have been related to mapping of fire fuels. The mapping has involved manual interpretation of large color composite prints. Responses indicate that results have been acceptable.

Utilization of SLAR to map lake depths was discussed. Data on this project is still being analyzed. Project may have significant impact on BLM capability to analyze hydrologic features in Alaska.

3. Future Applications Identified

Use of NOAA AVHRR to map fire fuels in Alaska environment.

B. State: Arizona
Number of Responses: 15

1. Photography Applications

Response described use of aerial photography in field offices. Range management use of photos for inventory and range improvement work was described. A realty specialist described use of photos to update land use maps. A more specialized use of photos to monitor impact of ORV activity was described.

2. Digital Processing Applications

Arizona has considerable experience with Landsat analysis. They were one of the ASVT states. Responses indicate that in general, the land cover mapping is not of fine enough detail for vegetation inventory work. Use of Landsat analysis as a preclassification tool for soil survey appears to have utility. Experience indicates that if trained personnel are involved, a cost-saving of 20 to 30 percent can be expected for soils preclassification. Woodland or fuel wood mapping products have been utilized by the field offices. Personnel training to be able to particpate in classification work and use data is lacking. Mobility is a problem.

A recent classification in the Arizona Strip District did not perform satisfactorily. Field checking was viewed as insufficient. A response indicated that "the framework used to identify vegetation ties appears too specific for classifying imagery but too general for resource application." A local capability to manipulate/classify this data is urged by several respondents. It was felt that this would facilitate greater input during classification and more use of the outputs.

Use of NOAA AVHRR data to map fire fuel types was discussed. A local assessment of 80 to 90 percent accuracy was offered.

3. Future Applications Identified

- range vegetation monitoring (seasonal and long-term)
- monitoring of wilderness areas
- monitoring erosional trends
- water quality
- monitoring mining rehabilitation plans

C. State: California
Number of Responses: 8

1. Photography Applications

Utilization of aerial photography in the forestry program was outlined in great detail. No other response related to aerial photography application.

2. Digital Processing Applications

Jet Propulsion Lab analysis in California Desert was discussed. Forage allocations were made. The data was used but is still questioned by many.

3. Future Applications Identified

- water source inventories
- erosion rehabilitative work
- range trend analysis
- location of historical features
- mineral applications - production verification, analysis of geologic hazard, inspection/enforcement, photogeology, lineament mapping, mapping hydrothermal alterations, mineral trespass

D. State: Colorado
Number of Responses: 16

1. Photography Applications

Utilization of CIR photos for water source inventory was detailed. Experience with low altitude photography was mixed. Appears suited in riparian environments. Doubtful applications in herbacious areas due to resolution. Successful utilization of 1:24,000 CIR photo interpretation for cover mapping in Piceance Basin. Chosen instead of available Landsat classification.

2. Digital Processing Applications

In general, use of Landsat to identify pinyon/juniper woodlands worked well. Most would use it again for this application. Specialized Landsat forest classifcations for Piceance area was very useful for resource area forester. Very pleased and would use again.

3. Future Applications Identified

- low level riparian trend work
- thermal for big game and wild horse counts
- occupancy trespass (realty)
- production verification (minerals)

E. State: Denver Service Center (D-470)
Number of Responses: 4

1. Photography Applications

Use of aerial photography for stream/riparian inventory and monitoring was discussed. Nine-by-nine (9x9) format preferable for ease of interpretation and filing. Should be directed at easily observed changes rather than subtle microchanges.

A comment pertaining to use of any remote sensing technique was offered as follows: must assure the technique can be understood and accepted by grazing permitter prior to implementation. This may avoid a kind of "black box" mentality which will cause the system to be undermined.

2. Digital Processing Applications

Response related using Landsat classification for special or unique sites or problem rather than broad areas. Consider temporal analysis.

3. Future Applications Identified

- change detection
- utilization
- precipitation patterns
- shrub characterization
- historical "dating" of disturbances resulting in different/new site potentials
- stream/riparian inventory and monitoring

F. State: Eastern States
Number of Responses: 12

1. Photography Applications

One response detailed the use of aerial photography for multi-resource evaluation.

2. Digital Processing Applications

Nearly all responses related to ESO's Landsat Inventory and Detection (LID) programs. Some responses (primarily from managers) were negative about aspects of the project. They questioned whether the benefits outweighed the costs. Oil and gas operations were not visible due to MSS resolution capabilities. Some responses support the LID effort and felt that it was the only cost-efficient method to monitor Federal Mineral Ownership in a 31-state area. Some changes were proposed in the present procedure.

3. Future Applications Identified

- mapping geologic structure
- correlation of Petroleum Information (PI) data with surface features (faults) and production
- trespass determination

G. State: Idaho
Number of Responses: 16

1. Photography Applications

Responses indicated use of several formats. Medium scale 9x9 used successfully to map vegetation. Was accurate and digitized for future GIS utilization. Small format (35 mm) helicopter photography for use in riparian environments was discussed. It was felt to be well-suited for this work and accurate. Minor details are not visible but significant features are easily noted and can be monitored. Also has utility in soil, water and air program to help select study sites and monitor effects of gully rehabilitation efforts. One response discussed the use of 35 mm photos to help in refinement of soil mapping units and range sites. Two examples of use of Optical Bar Photography were included. Agricultural trespass and fire rehabilitation work were successfully accomplished via Optical Bar.

2. Digital Processing Applications

Idaho was one of the ASVT states. Responses indicated that some utility was made of the outputs. Idaho feels the project was never really completed due to Washington Office budget realignment. Cover class data was used by field offices. Respondent felt more use could have been made. Agricultural trespass capabilities were a spin-off benefit of the ASVT.

The Boise District is currently involved in a Landsat classification effort with a local processing capability in Idaho state government. Results up to this time look encouraging. The local capability is much preferred.

Two responses pertaining to the Soda Springs project indicate extreme dissatisfaction. The scale of the outputs are inadequate and they do not expect to use the output.

3. Future Applications Identified

- vegetation trend monitoring using multilevel sampling
- techniques for digital compilation from photo interpretation (APPS-IV type equipment)
- erosion monitoring
- TM data for habitat evaluation
- TM data for agricultural trespass
- fire fuels loading
- SLAR for structural geology

H. State: Montana
Number of Responses: 6

1. Photography Applications

Responses indicated use of medium scale CIR for preliminary determination of alluvial valley floors. This data required as part of coal leasing procedure. Also, several large projects in eastern Montana and North Dakota involving contracted photo interpretation of medium and small scale CIR for mapping surface resource information. Information mapped included present vegetation, potential habitat types, land forms, current land uses, water developments, range improvements, and transportation networks. Responses indicate data was well utilized and provided current data to assist in land use planning efforts.

Use of large scale 35 mm photography for vegetation monitoring was discussed. Procedure is not operationally used. Detail appears insufficient on some sites. Requires specialized expertise to acquire and interpret data. Possible utilization in riparian vegetation and on "M" category allotments.

2. Digital Processing Applications

No responses.

3. Future Applications Identified

- monitor losses in forested acreages
- vegetation monitoring for "M" category allotments and riparian areas

I. State: Nevada
Number of Responses: 12

1. Photography Applications

Use of aerial photography for delineating range types and verifying the location of range improvements was detailed. This work was done in association with a range inventory.

2. Digital Processing Applications

Most of Nevada's experience with Landsat analysis appears to relate to soils premapping efforts. The general impression from some of the older work (1980-83) is that it generally did not provide enough detail for use at the field level. It was indicated that it only worked well in very distinct soil/vegetation types. One response described the use of a Landsat classification to produce a vegetation premap. The respondent felt that the data was usable but that it was really never used because of lack of understanding about the project goals. Two individuals commented about present (1984) involvement in the evaluation of the SLAP process. Although the procedure is not fully evaluated yet, both felt that the procedures appeared to have merit. One individual questioned whether the MSS data was adding significantly to the process.

3. Future Applications Identified

- range condition and monitoring of trend
- riparian mapping and monitoring
- use of radar for soil/water/air work
- inventory of water sources
- detecting unauthorized use
- fire fuels
- locating proposed range improvements
- evaluation of mineral potential
- multilevel remote sensing for land use planning

J. State: New Mexico
Number of Responses: 19

1. Photography Applications

Successfully used photography in assessment of instream flow requirements. References were made to the use of aerial photos during the SVIM process. A previous photo interpretation mapping project in 1976 was outlined and deemed to be largely unsuccessful. One reference to use of 35 mm photography for evaluation of herbicide application and watershed rehabilitation.

2. Digital Processing Applications

Very mixed feelings here. Several felt that the data was too gross and/or inaccurate. Others felt that the products were useful but too much was attempted. Opinion expressed that it was too general for range work. Wildlife biologist felt it was not detailed enough for his needs. Most were enthusiastic about ability to manipulate data via GIS. Some viewed the Landsat analysis as opening the door for GIS.

Opinions about woodland applications are also divided. Some felt it was inaccurate and of little use. Others felt it provided useful information about a resource that they had little information on previously.

3. Future Applications Identified

- monitoring wilderness areas
- cultural resource evaluation
- satellite weather information
- fire rehabilitation monitoring
- firewood areas
- snow pack analysis
- locating existing range improvements
- mapping prairie dog town (ferret surveys)

K. State: Oregon
Number of Responses: 10

1. Photography Applications

One response detailed the use of hand-held cameras to acquire oblique photos for vegetation control assessment, fire planning and timber sale review. Another response illustrated the use of 70 mm photos from helicopters for forest regeneration surveys and monitoring the effects of vegetation control. High altitude photography was interpreted for mapping of a noxious plant--Tansy Ragwort. Although the mapping was fairly successful, the area already had data as good. Photos may have more utility for monitoring spread. Low altitude aerial photos have been used for riparian monitoring quite successfully. A system for utilizing large scale photos for rangeland trend is being investigated in Baker.

2. Digital Processing Applications

A reference to a classification performed in Baker was included. The summary evaluation indicated it was not detailed enough for use by the field office.

3. Future Applications Identified

- use of airborne video in forest management -- post treatment work, thinning potential, etc.
- smoke monitoring (fire)
- evaluation of site productivity
- wildlife telemetry

L. State: Utah
Number of Responses: 8

1. Photography Applications

Response described used of 9x9 photos to inventory water resources. Was found to be accurate and cost effective.

2. Digital Processing Applications

Landsat map of wildfire burned area was discussed. Quality of product was excellent. Delivery of output was so slow that utility of product was minimal. If faster turnaround were possible, output could be of great value for Emergency Fire Rehabilitation Plan.

3. Future Applications Identified

- low altitude range monitoring
- wildfire mapping
- mapping geologic structure
- mine plan compliance, production verification

M. State: Wyoming
Number of Responses: 25

1. Photography Applications

Responses indicate a very broad use of aerial photography by many disciplines. Orthophoto quads are also used very extensively. Photos/orthos used heavily during SVIM process. Photos used to map vegetation types, locate range improvement projects, pipelines, reservoirs, roads, etc. Photos have also been utilized to locate and map historical trails. Large scale photos have been used to monitor oil/gas operations. Responses indicate good photo coverage has been maintained and current photos are available.

2. <u>Digital Processing Applications</u>

Responses indicated that <u>previous</u> projects did not live up to expectations. Detail and accuracy were not viewed as satisfactory and there was significant confusion due to soil reflectance. Several ongoing projects are attempting land cover mapping for incorporation into a GIS. No evaluation was possible on most since they are not completed. In one project, response indicated that sagebrush density breakdown looked good and should be useful. On another project, the soil reflectance was causing confusion and the classification appeared too gross for field office needs.

The Rock Springs District reported displeasure with some initial SLAP-type work performed in conjunction with EROS and DSC. Coordination was poor, timeframes did not meet District needs, and no real final report or evaluation was received.

3. <u>Future Applications Identified</u>

- monitor soil conservation efforts
- vegetation cover mapping
- investigate new cameras with increased capabilities (Image Motion Compensation) for vegetation mapping
- continue evaluation of automated remote sensing for vegetation mapping
- Landsat/TM for woodland inventory
- thermal sensing for mine pollution problems
- use of NHAP for wilderness evaluation and monitoring

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